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DEVELOPMENT OF PREDICTION TECHNIQUES FOR AERODYNAMIC LOADS ACTING ON EXTERNAL STORES

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General Dynamics

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GENERAL DYNAMICS, CONVAIR AEROSPACE DIVISION

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AIR FORCE FLIGHT DYNAMICS LABORATORY
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio 45433

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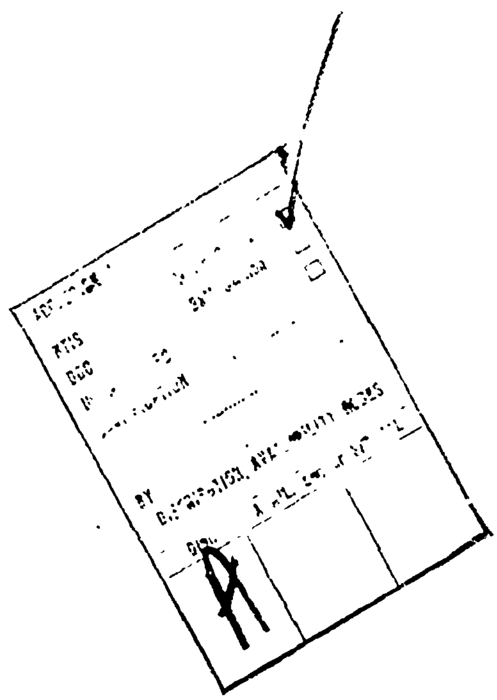

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DEVELOPMENT OF PREDICTION TECHNIQUES FOR AERODYNAMIC LOADS ACTING ON EXTERNAL STORES

M. B. Sullivan

FOREWORD

This report was prepared by General Dynamics' Convair Aerospace Division, Fort Worth, Texas, for the Air Force Flight Dynamics Laboratory, Directorate of Laboratories, Air Force Systems Command, United States Air Force, Wright-Patterson Air Force Base, Ohio. The study was conducted under Contract F33615-73-C-3011, Project 1367, Task 136702, Work Unit 1367C223 during the period from December 5, 1972, to November 1, 1973. Mr. George E. Muller (AFFDL/FBE) of the Structures Division, Structural Integrity Branch, Criteria and Applications Group, was the project engineer on this study.

The engineering studies accomplished under this contract were conducted within the Aerospace Technology Department, Aerodynamics Section, of the Convair Aerospace Division. Mr. M. B. Sullivan was the program manager during the contract period.

This technical report was submitted to the Air Force on May 13, 1974. This technical report has been reviewed and is approved.

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ABSTRACT

A preliminary design technique for the prediction of aerodynamic loads acting on external stores has been established through an empirical correlation of wind tunnel results obtained on a scale model of the F-111. Approximately 30,000 engineering data points were surveyed for various combinations of external stores. These data, originally stored on magnetic tape, were transferred to CDC 6600 disk packs. This was done to reduce the amount of computer run time required to collect the desired samples of data. For this study, correlations were performed on each aerodynamic component of load or moment acting on a particular store grouping as a function of various geo metry parameters. The work was accomplished primarily through the utilization of numerical programs in which, through a series of trial and error calculations, an equation composed of various key geometry parameters was generated. The equations obtained for the numerical programs predict normal force, side force, pitching moment, yawing moment, and rolling moment for various external store arrangements. These forces and moments are predicted at discrete angles of attack and angles of sideslip of the store. Sections 1 through 8 and Appendix I summarize the wind tunnel results utilized, the computer software developed to process the data and the results of the correlation studies. Appendix II contains the mathematical relationships to determine five components of aerodynamic force or moment acting on various external store arrangements. This appendix is self-contained so that it may be removed and used more conveniently. The mathematical relationships provided are intended for use in preliminary design.

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SECTION 1

INTRODUCTION

The development of military jet aircraft with improved thrust-to-weight ratios has allowed an increase in the number and types of weapons carried on externally mounted pylons. In addition, increased penetration speeds over target areas has resulted in greater aerodynamic forces and moments acting on the stores. These two factors require, even in the preliminary design stages, that a detailed structural analysis be conducted to ensure that only the minimal structural weight is added to resist the aerodynamic and inertial loads resulting from the stores.

Modern attack aircraft can mount a large variety of external stores simultaneously on multiple pylon locations. In order to obtain the aerodynamic data necessary in the design process, all of the major aircraft companies depend on extensive wind tunnel testing. As a result, several of the major aircraft companies have extensive libraries of wind tunnel results for aerodynamic force and moments acting on many varieties of external store configurations. The availability of large amounts of wind tunnel data offers the possibility that the prediction techniques could be developed based on an empirical correlation of the wind tunnel results to various pertinent geometry parameters. This would effectively generalize the data and allow application to other aircraft programs.

Studies are currently being conducted to develop analytical techniques for the prediction of aerodynamic loads acting on external stores. With high-speed digital computer equipment, very complex mathematical solutions may be obtained with reasonable machine run times. Reference 26 is a finite-element lifting-surface potential-flow-theory program that is capable of calculating surface pressure distributions for actual aircraft geometries. This procedure was developed from Reference 27 but was modified to obtain solutions at subsonic speeds and to allow for external bodies to be evaluated. The program in its present format, however, is useful for the solution of single-pylon arrangements only. This is primarily due to the number of lifting surfaces which may be input. With geometry representation of the aircraft, the limited number of control points allowed is quickly exceeded if a fin arrangement for anything more than a single

weapon is represented. In addition to this approach, attempts to solve the interference problem between adjacent stores are being made. As illustrated in Reference 28 some degree of success has been achieved. In total, however, it must be stated that the availability of analytical techniques for predicting external store aerodynamic loads in multiple store loadings is remote and empirical techniques based on a correlation of existing experimental data offer the best alternative at this time.

Most of the up-to-date testing to obtain external store aerodynamic loads has been accomplished utilizing miniature strain gages contained in the external store and designed to yield five and six components of aerodynamic force and moment data. During the F-111 program such instrumentation was employed on a 1/12th scale model of the complete configuration. During the testing as many as four pylon stations were instrumented simultaneously. All of these data were then recorded on magnetic tape for subsequent analysis utilizing digital computer equipment.

This backlog of experimental data formed the basis for the subsequent studies reported in this document. These studies were conducted to establish empirical prediction techniques for five components of force and moment acting on an individual store correlated to pertinent geometry parameters of the store and its location on the configuration.

The development of the prediction methods evolved in three steps:

- Formulation of a data library
- Selection of correlation techniques
- Application of the correlation techniques

The mass of F-111 1/12-scale model external store loads data formed the data library. These data contained on magnetic tapes was assembled on magnetic disk pack to reduce the digital computer run time for subsequent surveys during the actual correlation studies. To establish the geometric correlating parameters use was made of established statistical methods of regression analysis. The particular statistical technique coded for use with CDC 6600 digital computer equipment produced an equation which predicted the particular force or moment coefficient at a definite angle

of attack or angle of sideslip. Graphical comparisons of the predicted value of force or moment were then made with the actual experimental data.

SECTION 2

DATA LIBRARY FORMULATION

One of the most important aspects of the empirical study to develop prediction techniques for external stores was to establish a permanent library of experimental data. During the development of the F-111 a 1/12th scale model was built and instrumented to allow the measurement of aerodynamic forces and moments acting on various external store configurations. The F-111 has eight wing spanwise pylon locations and any pylon station is able to carry a single weapon or a cluster of as many as six weapons. Because of this flexibility a large variety of external store combinations were tested and all of the data taken were recorded on magnetic tape.

This section of the report illustrates the general arrangement of the F-111 airplane and defines the pylon and external stores geometries. Tables are included which show schematically the various total configurations tested with the location of the strain gage instrumentation noted.

2.1 F-111 Airplane - External Store Geometry

Wind tunnel testing of a 1/12th scale model was conducted with miniature strain gages installed in various external store arrangements to measure five components of aerodynamic force and moment acting on a store configuration. The components measured were normal force, side force, yawing moment, pitching moment, and rolling moment. Many types of stores were tested at subsonic, transonic, and supersonic speeds at wing-sweep angles from 16 to 72.5 degrees, at angles of attack of -5 to +20 degrees, and at sideslip angles of -10 and +10 degrees. In addition to these parameters, the broad range of configuration design parameters covered were:

- o Store type (store geometry)
- o Store arrangement on pylon
- o Pylon position on wing
- o Variations in pylon loading.

A three-view drawing of the F-111 is shown in Figure 1. Each half of the wing has four pylon stations. A movable pylon, shown in Figure 2, is mounted on the two inner stations, and a fixed pylon, also shown in Figure 2, is mounted on the two outer stations. Two types of racks (Figure 3) are used for attaching the stores - a triple-ejector rack capable of holding three stores (TER rack), and a multiple ejector rack capable of holding six stores (MER rack). Single stores were also attached directly to the pylon and tested.

The sign conventions for the left and right wings are shown in Figures 4 and 5, respectively. Figure 6 shows the wing planform with the pylon stations for 16° wing sweep and tabulated data is presented for other sweeps.

The orientation of the fins for several of the stores on MER or TER racks is demonstrated in Figure 7. Detailed dimensions of the stores racks and pylon tested are given in Figures 8 through 17.

2.2 F-111 Wind Tunnel Program

The various external store configurations tested on the F-111 are defined in Table I. This table gives the designation of the various stores tested at the various pylon stations, a schematic of the store arrangement and the pylon stations occupied, the rack employed, and the actual station where the strain gage was mounted to obtain the aerodynamic loads. Additional information illustrates the specific Mach number and wing sweep angles tested.

An identification of the test is contained in the next to last column. This is the number used by the test facility to identify a particular wind tunnel test program. All was accomplished at the AEDC 16-foot facility. A limited number of configurations were tested at subsonic Mach numbers from 0.2 to 0.6 at the 12-foot pressure tunnel at NASA Ames.

As illustrated in Table I the store arrangement on the left wing is defined. The strain gages on this wing were installed in such a manner that aerodynamic loads acting on the complete store plus rack plus pylon were measured. The complete airplane configuration was always tested symmetrically and in the right wing strain gage instrumentation was installed to record the aerodynamic loads on the store plus rack only. This of course produced two complete sets of data for each store configuration tested.

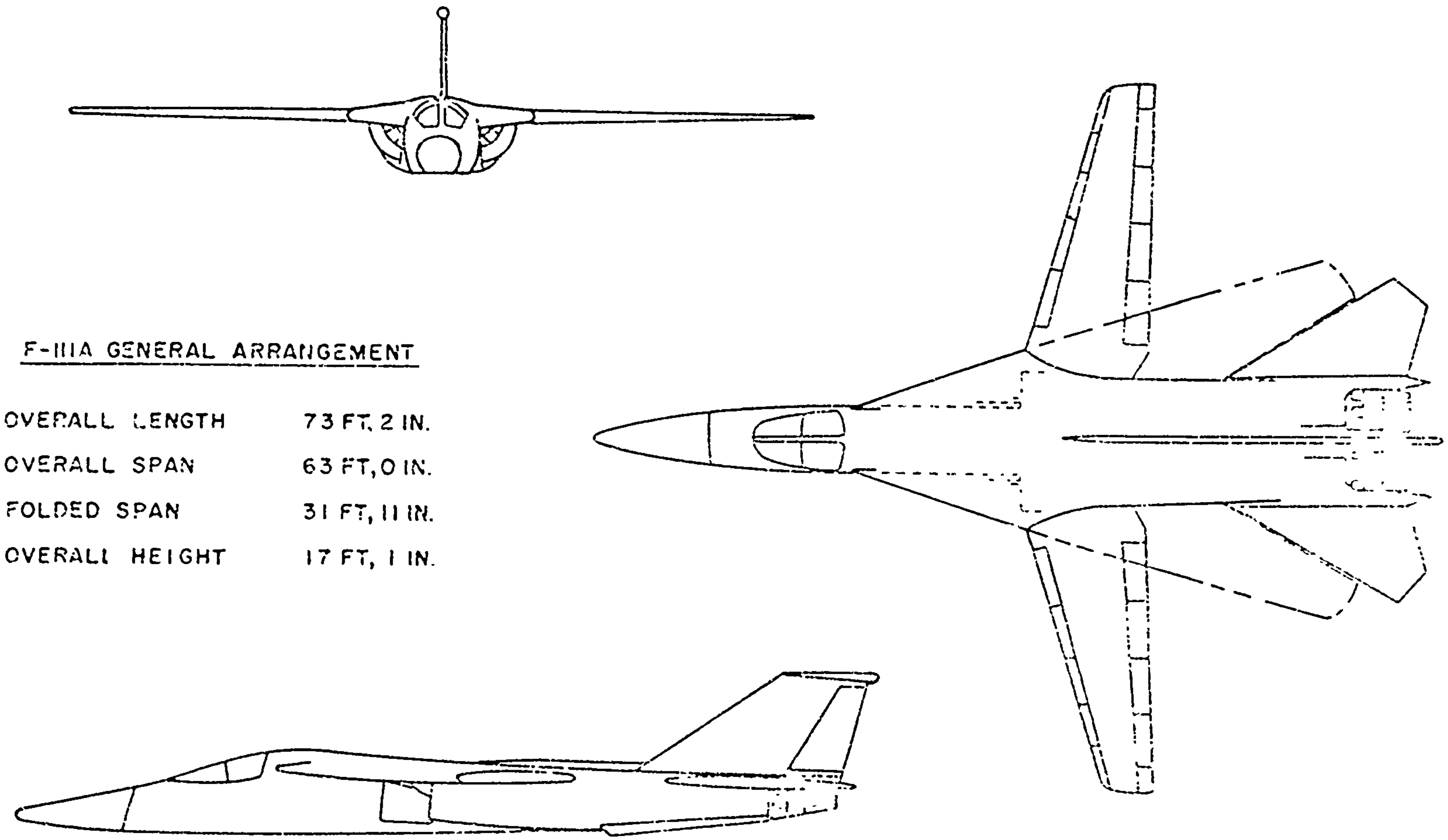
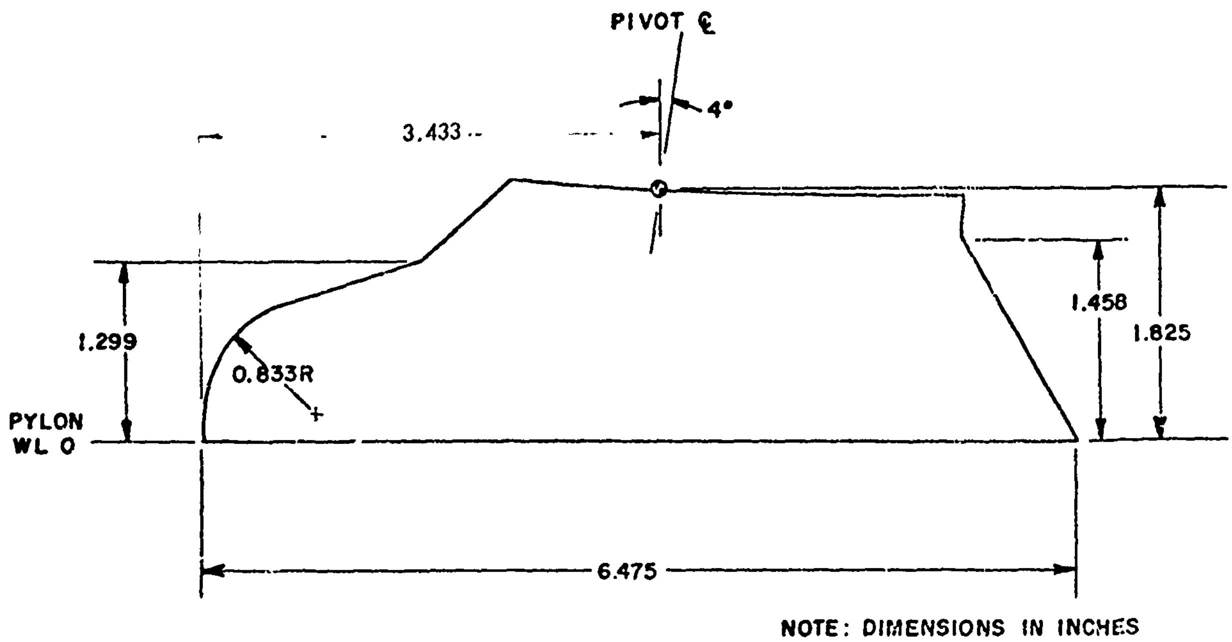
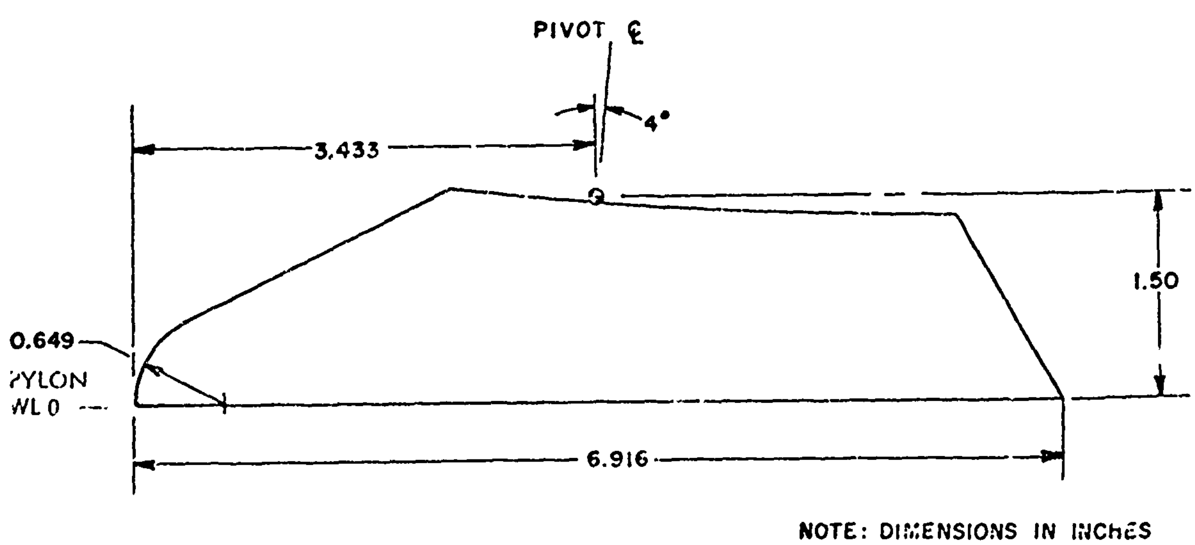


Figure 1 GENERAL ARRANGEMENT OF THE F-111A MODEL

1/12-Scale Model Dimension



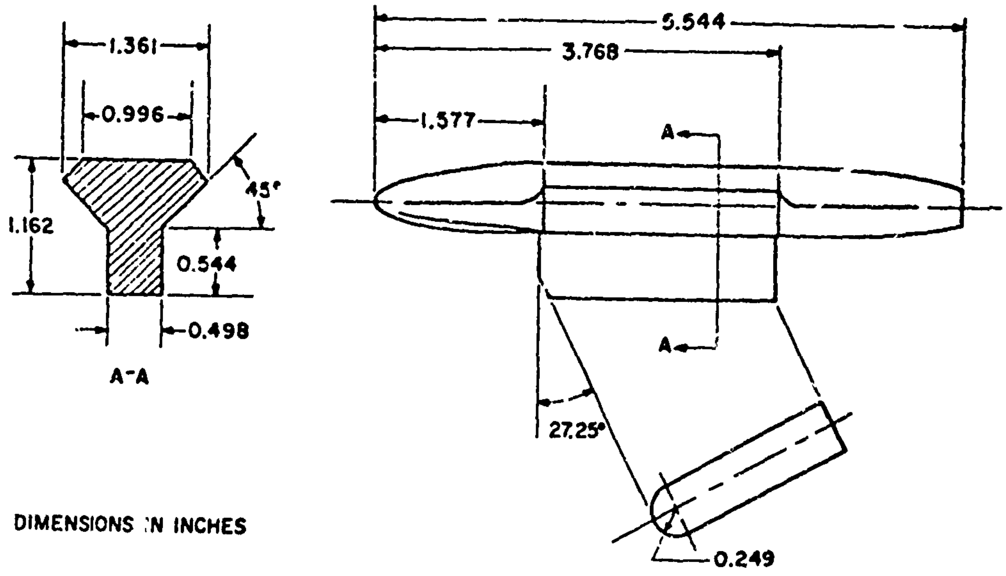
Fixed Pylon



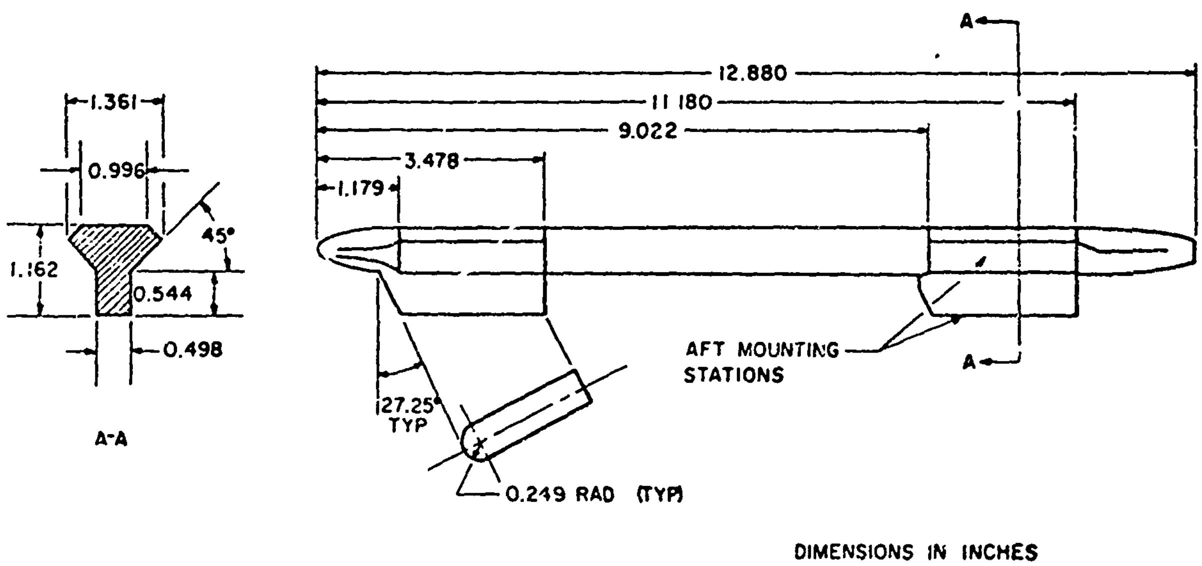
Pivoted Pylon

Figure 2   FIXED AND PIVOTING PYLON DIMENSIONS

1/12-Scale Model Dimension



g. Triple Ejector Rack



f. Multiple Ejector Rack

Figure 3 RACK CONFIGURATION

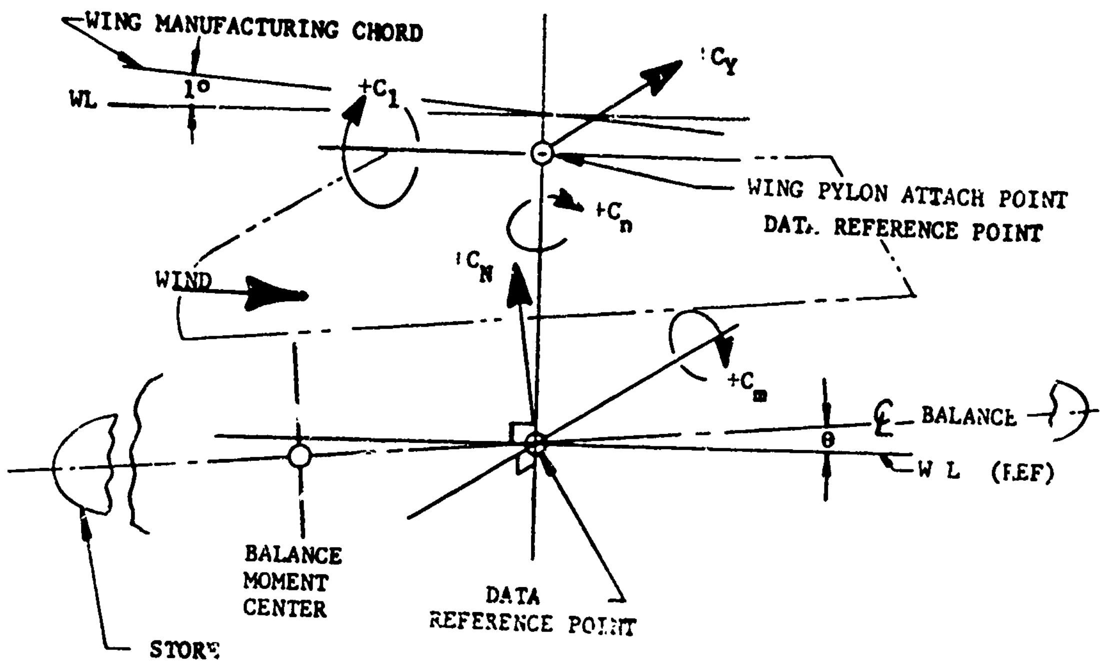


Figure 4 LEFT WING SIGN CONVENTION

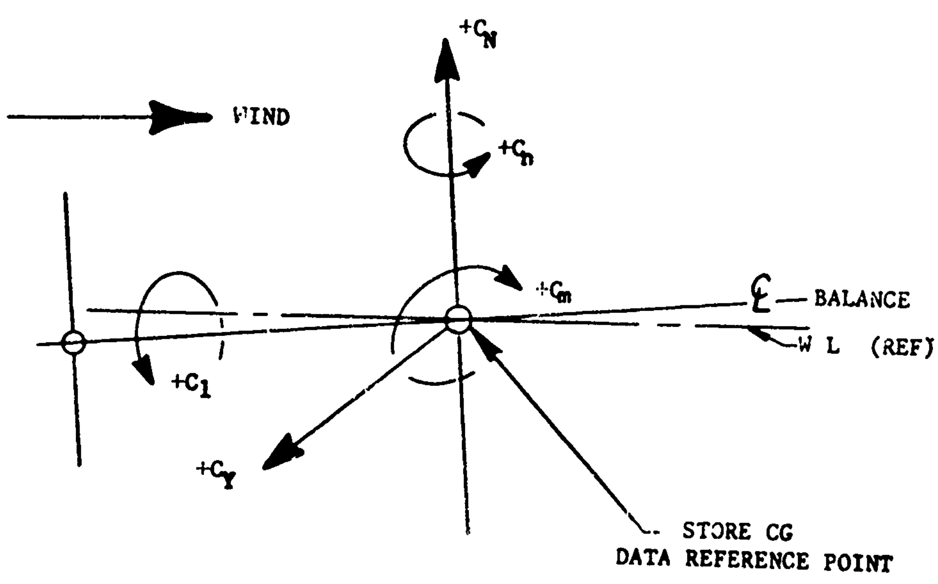
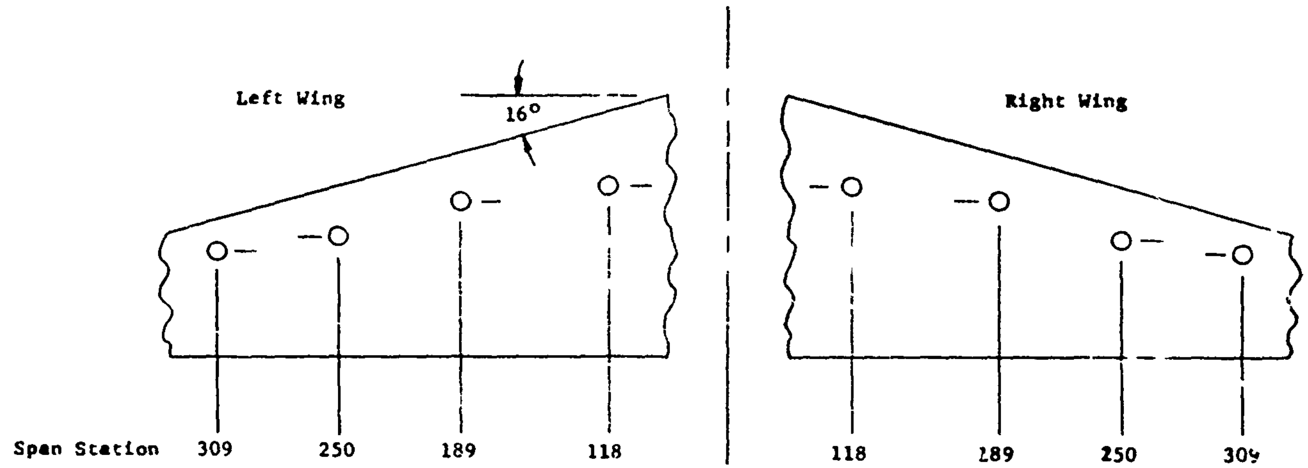


Figure 5 RIGHT WING SIGN CONVENTION



Λ = 16°				Λ = 26°				Λ = 35°				Λ = 50°				Λ = 72.5°			
Span = 755.910				Span = 719.944				Span = 676.585				Span = 579.072				Span = 383.8			
Span Sta.	% Span	Chord	% Chord	Span Sta.	% Span	Chord	% Chord	Span Sta.	% Span	Chord	% Chord	Span Sta.	% Span	Chord	% Chord	Span Sta.	% Span	Chord	% Chord
118	.312	119.04	.3040	115	.319	123.10	.3147	110	.325	130.64	.3255	101	.349	155.29	.3491	84	.438	270.04	.4297
189	.50	99.90	.2374	183	.508	102.96	.2464	175	.517	108.90	.2557	156	.539	128.47	.2764	116	.604	217.67	.3492
250	.66	83.34	.3057	240	.667	86.20	.3162	227	.671	91.48	.3269	196	.677	108.75	.3507	134	.698	189.21	.4313
309	.818	67.46	.2365	297	.825	69.53	.2454	280	.828	73.54	.2547	240	.829	86.74	.2754	160	.834	146.90	.3481

Figure 6 PLANFORM VIEW OF F-111 STATIONS

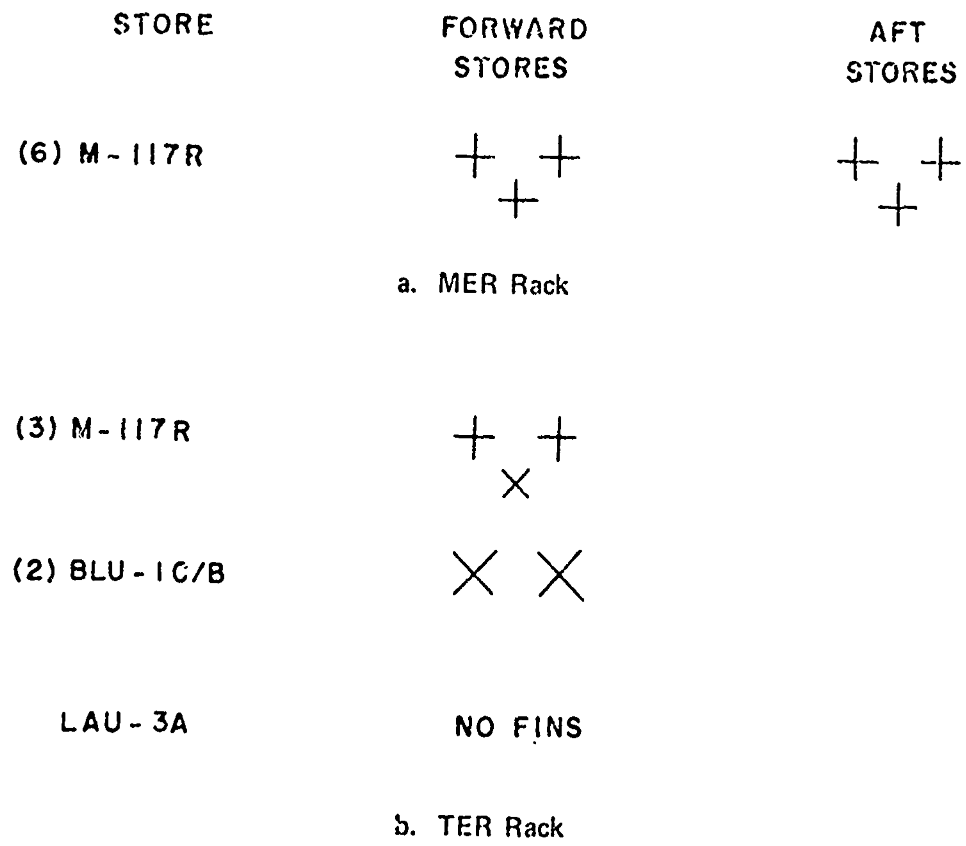


Figure 7 STORE FIN ORIENTATION ON EJECTOR RACKS

1/12-Scale Model Dimension

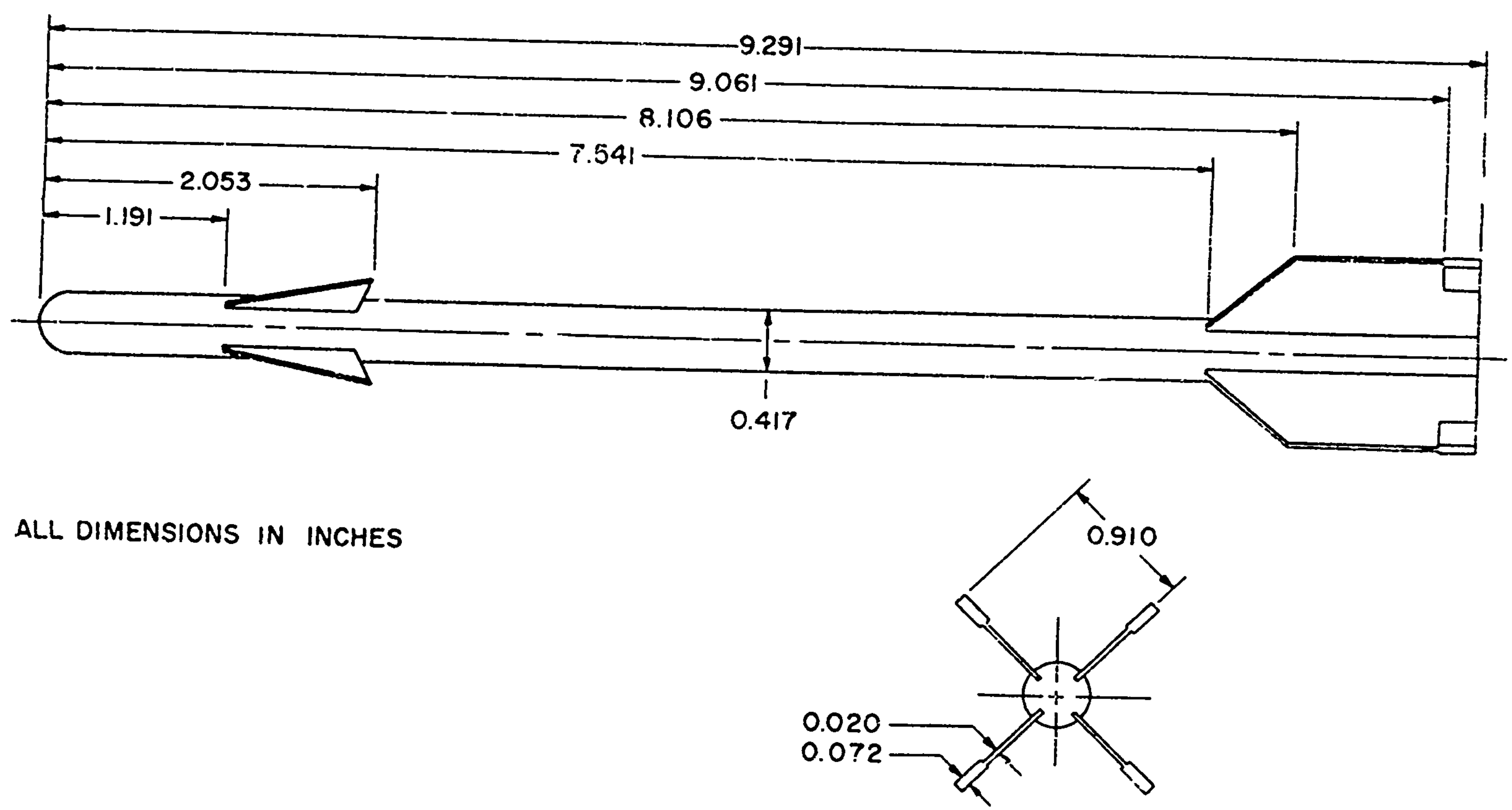


Figure 8 AIM-9B

1/12-scale Model Dimension

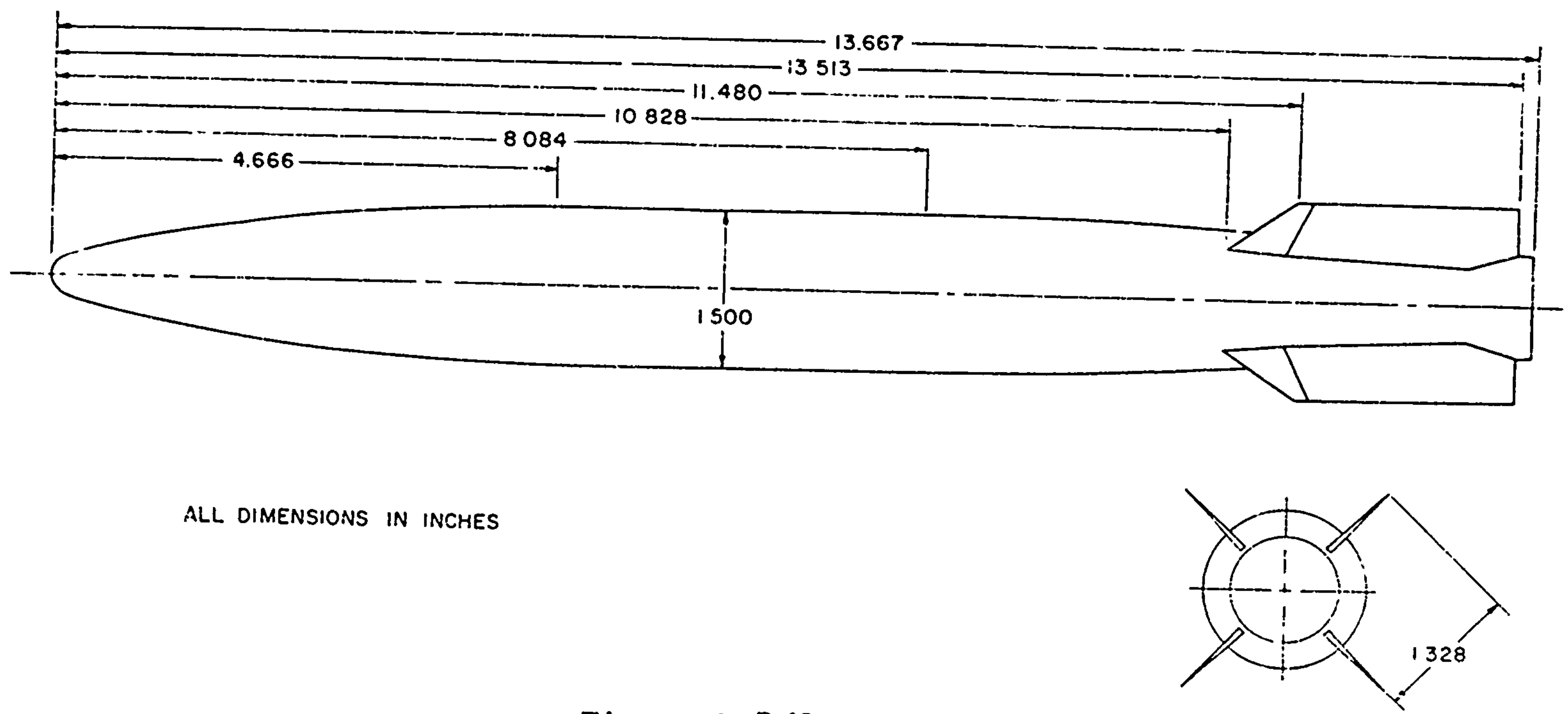


Figure 9 B-43

1/12-Scale Model Dimension

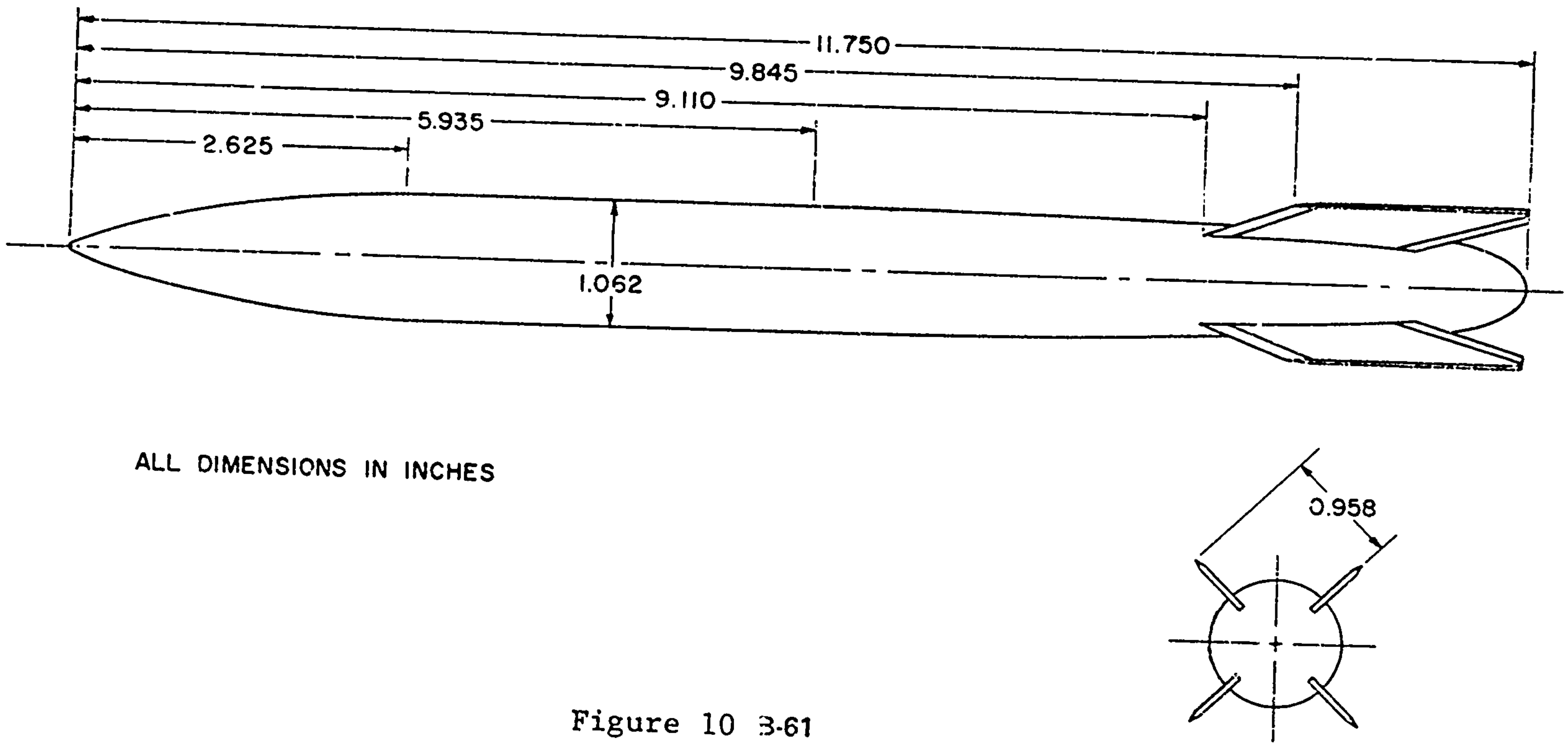


Figure 10 B-61

1/12-Scale Model Dimension

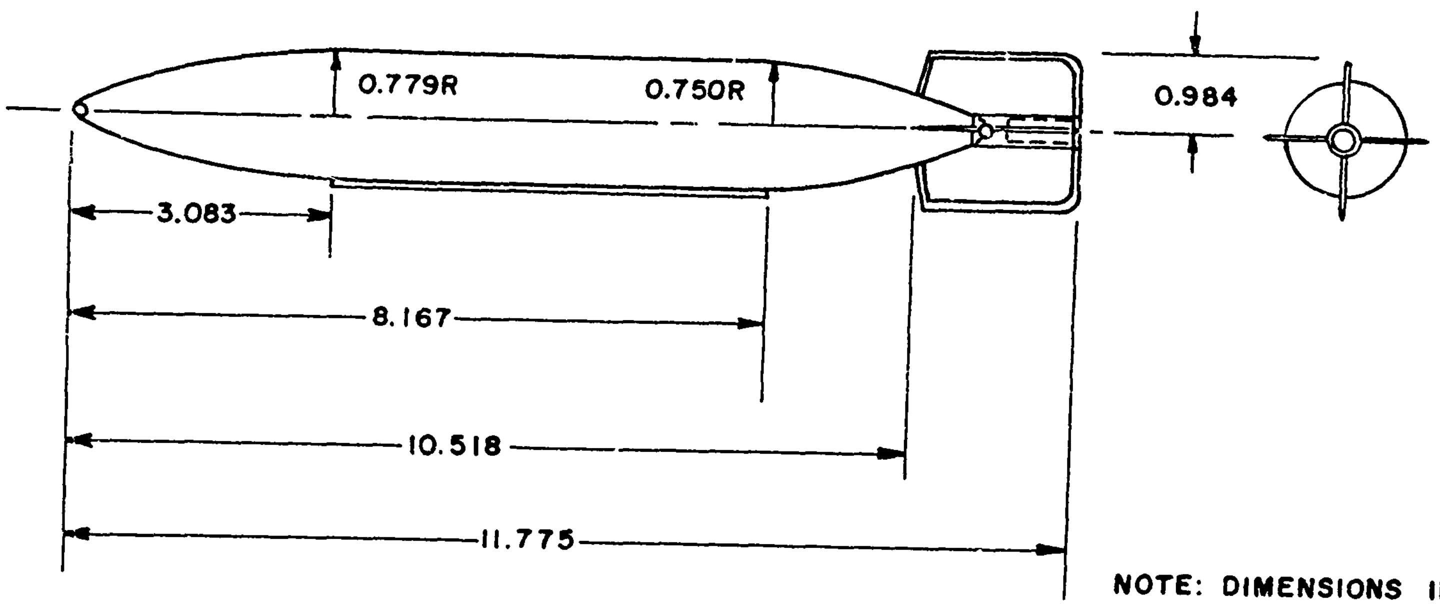


Figure 11 BLU-1C/B

1/12-Scale Model Dimension

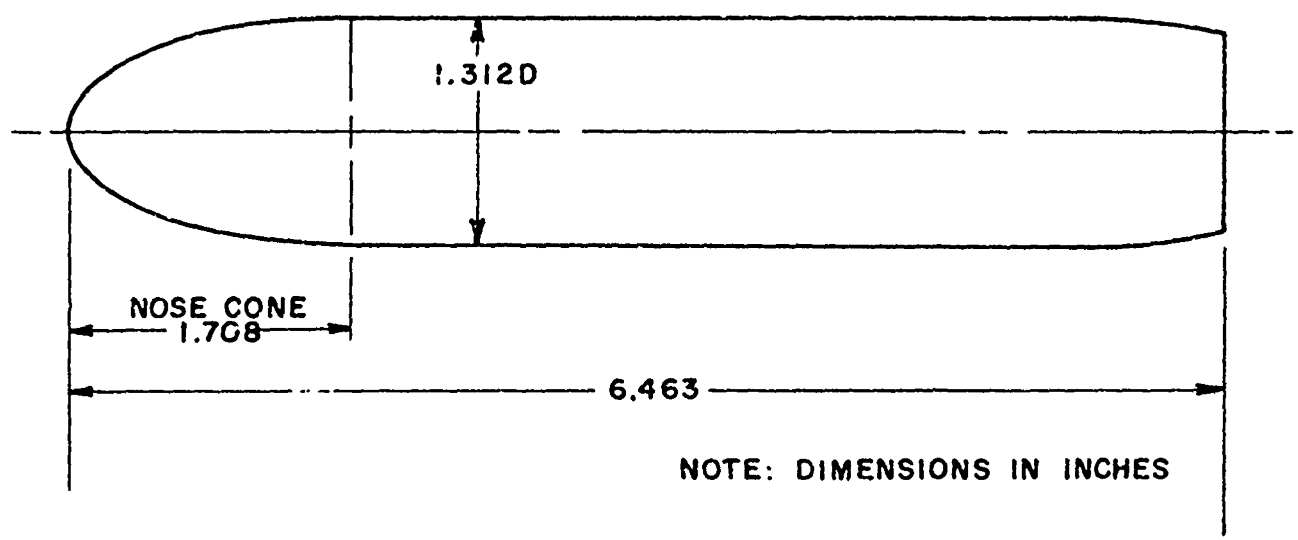


Figure 12 LAU-3/A

1/12-Scale Model Dimension

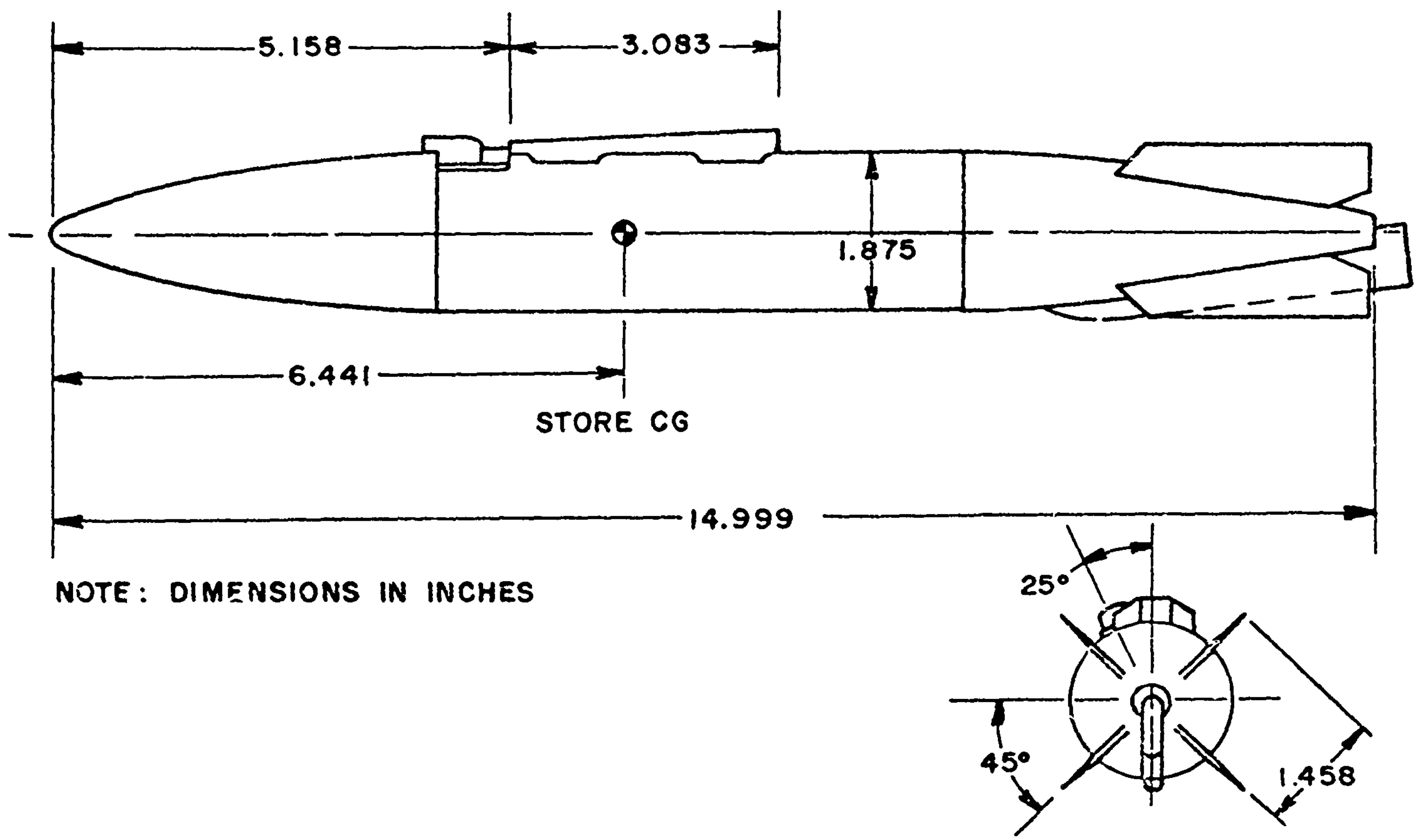


Figure 13 TMU-28/B

1/12-Scale Model Dimension

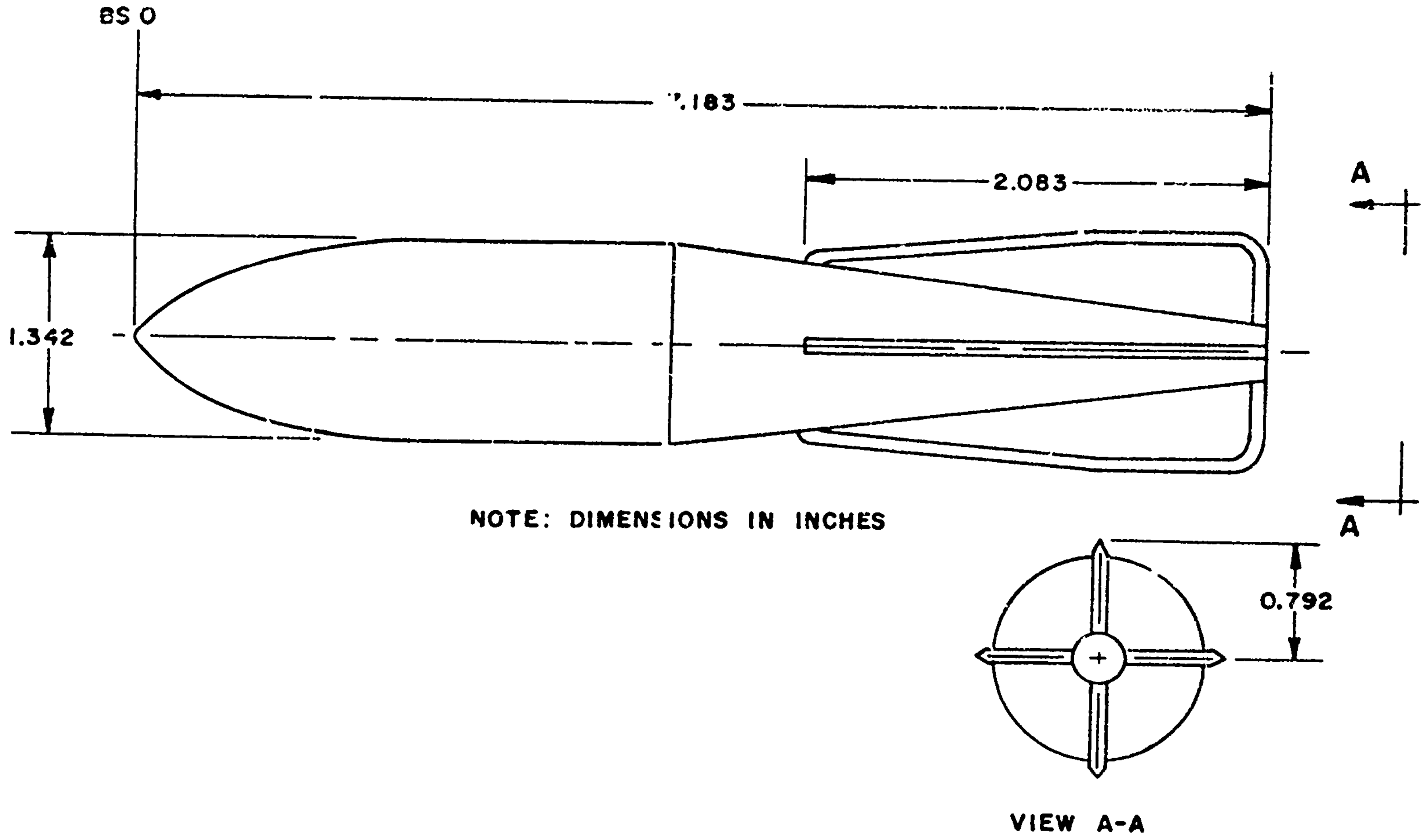
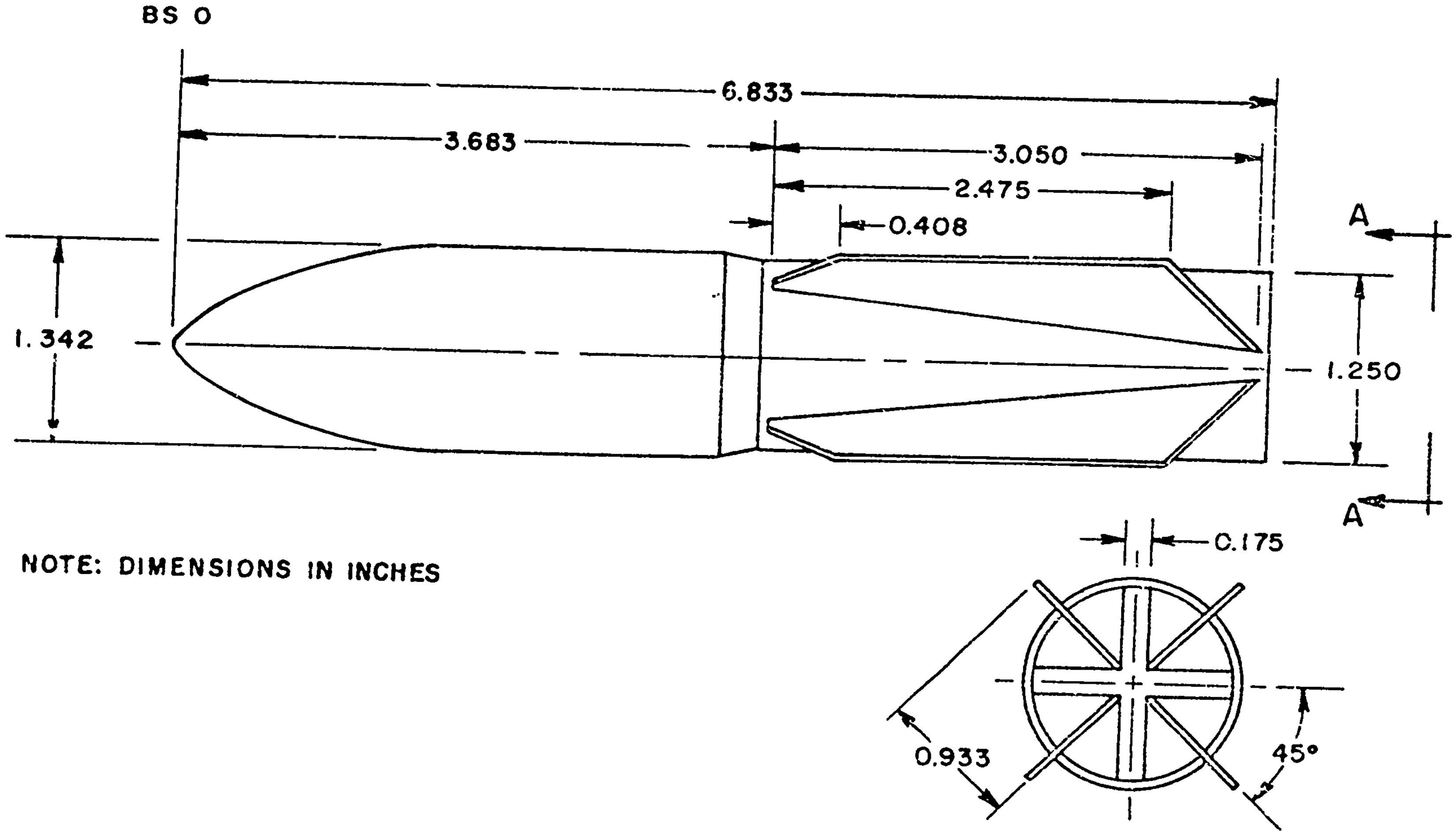


Figure 14 M-117

1/12-Scale Model Dimension



NOTE: DIMENSIONS IN INCHES

Figure 15 M-117R

1/12-Scale Model Dimension

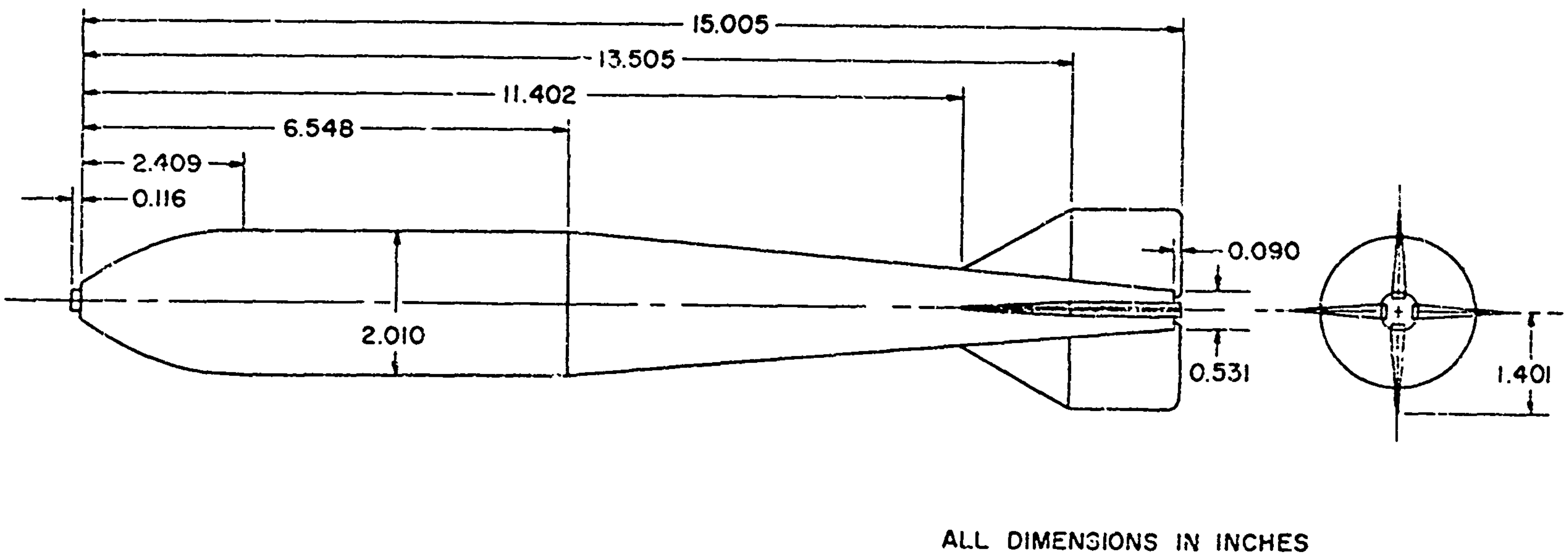


Figure 16 M-118

1/12-Scale Model Dimension

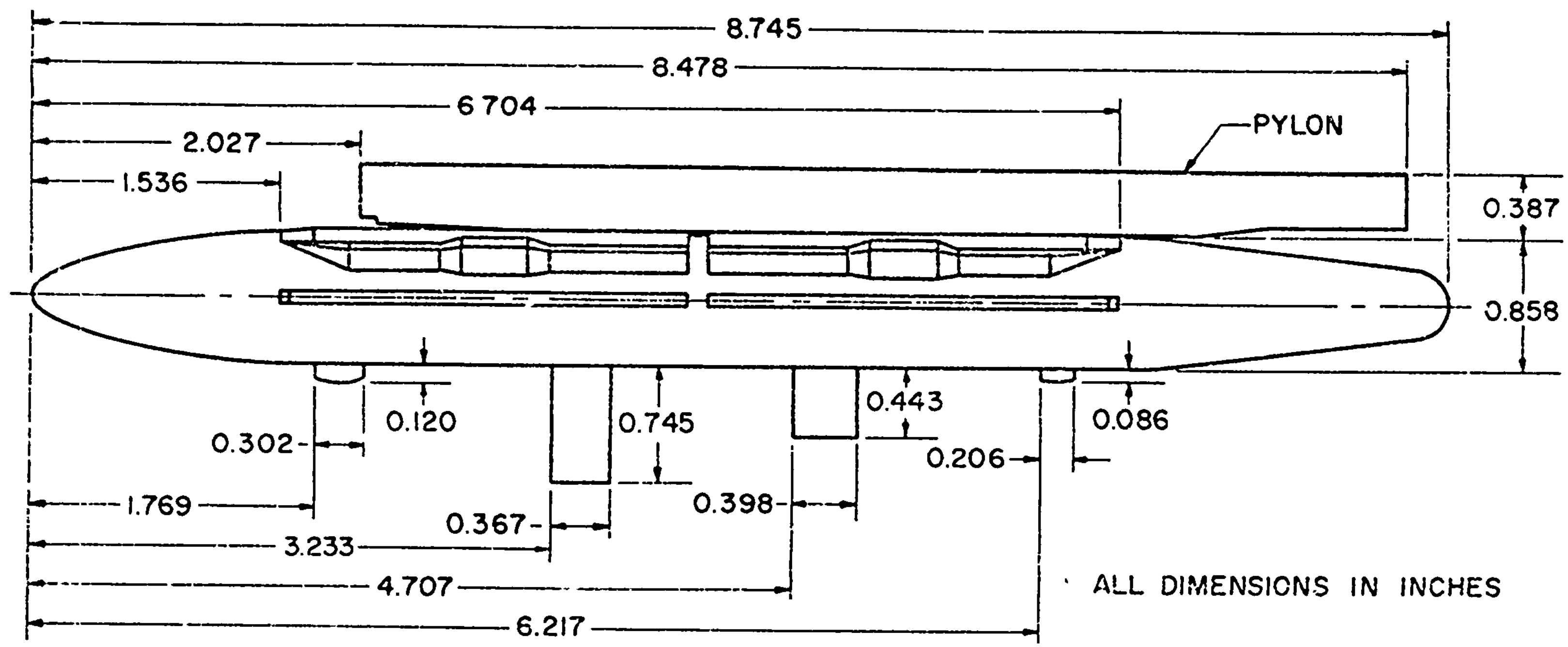


Figure 17 QRC POD

TABLE I F-111 WIND TUNNEL TEST PROGRAM

EXTERNAL STORE	PYLON STATIONS 4 & 5	3 & 6	2 & 7	1 & 8	Λ_{LE}	MACH RANGE	TEST	COMMENTS
24 M-117R	M	M	—	—	16° & 26°	0.25 → 0.6	ARC-12-431	
16 BLU-1C/B w/o FINS	T	T	T *	T *	16° & 26°	0.25 → 0.6	↓	* INSTRUMENTED STATIONS
16 BLU-1C/B w/o FINS	T *	T *	T	T	26°	0.25 → 0.6	↓	* INSTRUMENTED STATIONS
12 BLU-1C/B w/FINS	T	T *	T *	—	16° & 26°	0.25 → 0.6	↓	* INSTRUMENTED STATIONS
24 LAU-3/A w/NOSE FAIRINGS	T	T	T *	T *	16° & 26°	0.25 → 0.6	↓	* INSTRUMENTED STATIONS
4 TMU-28/B	—	O	O	—	16° & 26°	0.25 → 0.6	↓	
4 M-118	O	O	—	—	26°	0.25 → 0.6	↓	
2 600 GAL. TANKS & 2 B-61	O	O *	—	—	16° & 26°	0.25 → 0.6	ARC-12-431	* INSTRUMENTED STATION

HI-LIFT CONFIGURATION: Flap Deflection 30°, Slat Deflection (#1 and #2) 50°, Slat Deflection (#3 and #4) 45°, Rotating Glove 15°, Clamshell Door 88°, Nose and Main Gear Doors Closed, Weapons Bay Doors Closed, No Horizontal Tail Deflections

Note: M = MER Rack, T = TER Rack

Table I Continued

EXTERNAL STORE	PYLON STATIONS 4 & 5	3 & 6	2 & 7	1 & 8	Λ_{LE}	MACH RANGE	TEST	COMMENTS
8 BLU-1C/B w/FINS	$\overset{2}{T}$	$\overset{2}{T}$	—	—	26°, 35° & 50°	0.6 → 1.2	TF-199 TF-244	ALSO w/SPEED BRAKE DEFLECTIONS OF 25° & 50° TO 0.95 M
4 BLU-1C/B w/FINS	$\overset{2}{T}$	Pylon T	—	—	26°, 35° & 50°	0.6 → 1.2	TF-199 TF-244	ALSO w/SPEED BRAKE DEFLECTIONS OF 25° & 50° TO 0.95 M
24 M-117R	$\overset{6}{M}$	$\overset{6}{M}$	—	—	26°, 35° & 50°	0.6 → 1.2	TF-199 TF-215 TF-233	ALSO w/SPEED BRAKE DEFLECTIONS OF 25°, 37.5° & 50°
16 M-117R	$\overset{4}{M}$	$\overset{4}{M}$	—	—	26°, 35° & 50°	0.6 → 1.2	TF-215	ALSO w/QRC-160 POD ON FUSELAGE
12 M-117R	$\overset{3}{T}$	$\overset{3}{T}$	—	—	26°, 35° & 50°	0.6 → 1.2	TF-199	
12 M-117R	$\overset{6}{M}$	Pylon M	—	—	26°, 35° & 50°	0.6 → 1.2	TF-199 TF-233	ALSO w/SPEED BRAKE DEFLECTIONS OF 25° & 50° TO 0.95 M
12 M-117R	—	$\overset{6}{M}$	—	—	26°, 35°, 50° & 72.5°	0.6 → 1.2	TF-215	ALSO w/SPEED BRAKE DEFLECTIONS OF 25°, 37.5° & 50°
12 M-117R	—	$\overset{6}{M}$	—	—	26° & 50°	0.6 → 1.2	TF-244	SPEED BRAKE DEFLECTED 0° & 50° WITH SPOILER DEFLECTIONS OF 20° & 45°
12 M-117R	$\overset{6}{M}$	—	—	—	26°, 35° & 50°	0.6 → 1.2	TF-215	ALSO w/QRC-160 POD ON FUSELAGE
8 M-117R	$\overset{4}{M}$	Pylon M	—	—	26°, 35° & 50°	0.6 → 1.2	TF-215	SLANT FOUR
8 M-117R	—	$\overset{4}{M}$	—	—	26°, 35° & 50°	0.6 → 1.2	TF-215	FLAT FOUR
6 M-117R	$\overset{3}{T}$	Pylon T	—	—	26°, 35° & 50°	0.6 → 1.2	TF-199	
12 M-117R & 6 LAU-3/A w/NOSE FAIRINGS	$\overset{6}{M}$	$\overset{3}{T}$	—	—	26°, 35° & 50°	0.6 → 1.2	TF-199	

Table I Continued

EXTERNAL STORE	PYLON STATIONS 4 & 5	3 & 6	2 & 7	1 & 8	Λ_{LE}	MACH RANGE	TEST	COMMENTS
12 LAU-3/A w/NOSE FAIRINGS	T	T	—	—	26°, 35° & 50°	0.6 → 1.2	TF-215	
6 LAU-3/A w/NOSE FAIRINGS	T	Pylon T	—	—	26°, 35° & 50°	0.6 → 1.2	TF-215	
6 LAU-3/A w/NOSE FAIRINGS	Pylon M	T	—	—	26°, 35°, 50° & 72.5°	0.6 → 1.2	TF-215 TF-220	50° SWEEP ONLY AT 1.05 & 1.2 M FOR TF-220
24 LAU-3/A w/NOSE FAIRINGS	T	T	T *	T *	16° & 26°	0.6 → 1.05	TF-220	* INSTRUMENTED STATIONS
18 LAU-3/A w/NOSE FAIRINGS	T	T *	T *	Pylon T	26°	0.6 → 1.05	TF-220	* INSTRUMENTED STATIONS
4 600 GAL. TANKS			—	—	26°, 35° & 50°	0.6 → 0.95	TF-233	w/SPEED BRAKE DEFLECTIONS OF 25° & 50°
2 600 GAL. TANKS		Pylon	—	—	26°, 35° & 50°	0.6 → 0.95	TF-244	w/SPEED BRAKE DEFLECTIONS OF 25° & 50°
2 600 GAL. TANKS	—		—	—	26°, 35°, 50° & 72.5°	0.6 → 0.95	TF-244	w/SPEED BRAKE DEFLECTIONS OF 25° & 50°
16 BLU-1C/B w/FINS	T	T	T *	T *	16° & 26°	0.6 → 1.05	TF-199	* INSTRUMENTED STATIONS
12 BLU-1C/B w/FINS	T	T *	T *	Pylon T	26°	0.6 → 1.05	TF-199	* INSTRUMENTED STATIONS

Table I Continued

EXTERNAL STORE	PYLON STATIONS 4 & 5	3 & 6	2 & 7	1 & 8	Λ_{LE}	MACH RANGE	TEST	COMMENTS
2 B-61 & 4 AIM-9B	○	2 ○T○	—	—	50° & 72.5°	1.4 → 2.2	TF-215 SF-119	ALSO w/SPEED BRAKE DEFLECTIONS OF 25°, 37.5° & 50° FROM 1.8 M TO 2.2 M
2 B-43 & 4 AIM-9B	○	2 ○T○	—	—	50° & 72.5°	1.05 → 2.2	TF-215 TF-220 SF-119	ALSO w/SPEED BRAKE DEFLECTIONS OF 25°, 37.5° & 50°
2 TMU-28/B	—	○	—	—	26°, 35°, 50° & 72.5°	0.6 → 1.6	TF-199 TF-244	ALSO w/SPEED BRAKE DEFLECTIONS OF 25° & 50° TO 1.4 M
4 B-43	○	○	—	—	50° & 72.5°	1.05 → 1.6	TF-233	WITH SPEED BRAKE DEFLECTIONS OF 25° & 50°
4 B-43	○	○	—	—	26°, 35°, 50° & 72.5°	0.6 → 1.6	TF-215	WITH QRC-160 POD ON FUSELAGE
2 M-118	—	○	—	—	26°, 35°, 50° & 72.5°	0.6 → 1.6	TF-233	ALSO w/SPEED BRAKE DEFLECTIONS OF 25° & 50°
2 M-118	○	Pylon	—	—	26°, 35°, 50° & 72.5°	0.6 → 1.4	TF-215 TF-233	ALSO w/SPEED BRAKE DEFLECTIONS OF 25° & 50° TO 0.95 M
4 M-118	○	○	—	—	26°, 35°, 50° & 72.5°	0.6 → 1.2	TF-215 TF-220 TF-233	ALSO w/SPEED BRAKE DEFLECTIONS OF 25° & 50° TO 0.95 M, and w/SPEED BRAKE DEFLECTIONS OF 25°, 37.5° & 50° FROM 1.05 M TO 1.4 M
12 LAU-3/A w/o NOSE FAIRINGS	3 ○T○○	3 ○T○○	—	—	26°, 35° & 50°	0.6 → 1.2	TF-199	
6 LAU-3/A w/o NOSE FAIRINGS	3 ○T○○	Pylon T	—	—	26°, 35° & 50°	0.6 → 1.2	TF-199	

Table I Continued

EXTERNAL STORE	PYLON STATIONS 4 & 5	3 & 6	2 & 7	1 & 8	Λ_{LE}	MACH RANGE	TEST	COMMENTS
36 M-117R	6 M	6 M	3 T *	3 T *	16° & 26°	0.6 → 1.05	TF-199	* INSTRUMENTED STATIONS
30 M-117R	6 M	6 M *	3 T *	Pylon T	26°	0.6 → 1.05	TF-199	* INSTRUMENTED STATIONS
16 BLU-1C/B w/o FINS	2 T	2 T	2 T *	2 T *	16° & 26°	0.6 → 1.05	TF-220	* INSTRUMENTED STATIONS
24 LAU-3/A w/o NOSE FAIRINGS	3 T	3 T	T *	3 T *	16° & 26°	0.6 → 1.05	TF-199	* INSTRUMENTED STATIONS
18 LAU-3/A w/o NOSE FAIRINGS	3 T	3 T *	3 T *	Pylon T	26°	0.6 → 1.05	TF-199	* INSTRUMENTED STATIONS
4 TMU-28/B	—	○	○	—	26°	0.6 → 1.05	TF-199	
4 TMU-28/B	—	○	○	—	16°	0.6 → 0.95	TF-244	

2.3 Data Retrieval From Magnetic Tapes

The wind tunnel data generated by the testing described in Section 2.2 and Table I was stored in a total of 16 magnetic tapes for processing by CDC 6600 digital computer equipment. The initial phases of the studies described in this report were concentrated on the development of the digital computer procedures used to retrieve the specific configurations from the magnetic tapes. Details of the methods used are described below and are shown schematically in Figure 18.

2.3.1 Disk Pack Storage

The test data originally stored on magnetic tape was first transferred to magnetic disk pack. This was done to reduce the computer machine run times to acceptable levels during the survey for particular groups of external store force or moment data. A convenient code number listed in Table II was used to identify the particular instrumented store. A File Identification Number (File ID.) was entered in the magnetic tape for each total configuration tested and is illustrated in Table III in the second column. This number was carried into the program to store the data on magnetic disk pack.

A problem that was evident very early in the development of the procedures was that several disk packs would be required to load all data from the sixteen magnetic tapes. This problem was unique to the CDC equipment in that a word length in disk pack is a fixed value of 64, and this value could not be varied. Most of the data loaded required only one third of this word length, leaving almost two thirds of the storage capacity of the disk pack unused.

For the actual loading operation of the disk pack one magnetic tape at a time was processed. On several occasions difficulties in loading a tape resulted in a complete loss of all data on a disk pack. So that the information successfully loaded on a disk pack would be protected a new system of computer procedures were coded. Under this system, all information loaded on the disk pack was recorded prior to the next attempt to load an additional magnetic tape on the disk pack.

During the conversion from tape to disk pack, the test data were nondimensionalized with respect to store geometry rather than airplane geometry parameters. Also, tables of geometric data corresponding to the various store types were included on the disk for the planned correlation studies.

2.3.2 Retrieval of Data From the Disk Pack

A second computer procedure (Code A7A) was written to retrieve selected data from the disk packs in a convenient format for use in correlation studies. Tabulated and plotted data are obtained from this program.

A sample of the tabulated data is shown in Table IV. A sample of plotted data from Procedure A7A is shown in Figure 19. The normal force coefficient for a specific store as a function of angle of attack at various sweeps is shown in the figure. The plotted data were valuable in detecting errors in the test data and in interpolating data at angles of attack or side slip not explicitly run in the test program.

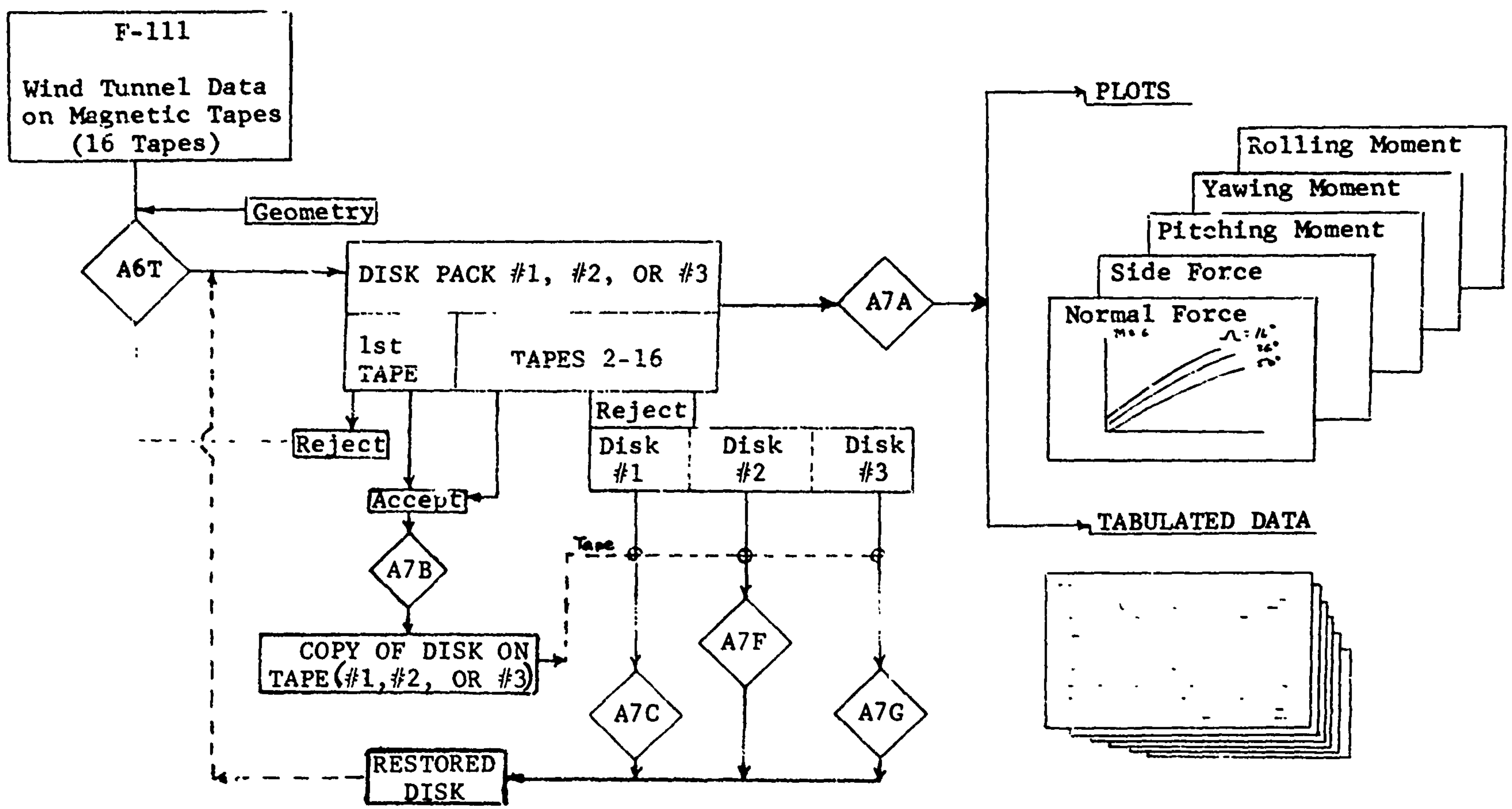


Figure 18 DATA RETRIEVAL PROGRAM SCHEMATIC

Table II CODE FOR STORE TYPE IDENTIFICATION

Configuration Code	Store Type
1	B43
2	B61
3	TMU-28/B (Full)
4	Empty Pylon (Pivot)
5	MER + Pylon (Pivot)
6	BLU-1C/B, Fins (2 on TER)
7	M-117R (3 on TER)
8	M-117R (6 on MER)
9	LAU-31A, w Nose, (3 on TER)
10	LAU-31A, w/o Nose (3 on TER)
11	TER + Pylon (Pivot)
12	M-117R, S4 on MER
13	M-117R, Flat 4 on MER
14	M-118
15	AIM-9B, Slant 2
16	BLU-1C/B, w/o Fins (2 on TER)
17	450-gal Tank
18	M61 Gun Pods
19	AIM-54A, Phoenix
20	600-gal Tank
21	Tow Target
22	AGM-65 (3 Symmetric)
23	Martel TV
24	Martel TV + Launcher
25	Martel RDR (AJ-168 AR)
26	MK-10 (Slant 4)
27	TV Pod (Stores on Wing)
28	AGM-65 (2 Symmetrical)
29	AGM-65 (2 AI)
30	AGM-65 (2 AO)
31	TMU 281B (Full) Fixed Pylon
32	MER + Pylon Fixed Pylon
33	BLU-1C/B, Fins (2 on TER) Fixed Pylon
34	M-117R (3 on TER) Fixed Pylon
35	M-117R (6 on MER) Fixed Pylon

Table II CODE FOR STORE TYPE IDENTIFICATION (Cont'd)

Configuration Code	Store Type
36	LAU-3/A, w Nose (3 on TER) Fixed Pylon
37	LAU-3/A, w/o Nose (3 on TER) Fixed Pylon
38	TER + Pylon Fixed Pylon
39	450-gal Tank Fixed Pylon
40	600-gal Tank Fixed Pylon
41	MK-10 (Slant 4) Fixed Pylon
42	MK-10 (Slant 4) 7.5" Fwd
43	MK-10 (Slant 4) 7.5" Fwd Fixed Pylon
44	TV Pod (No Stores on Wing)
45	BLU-1C/B, w/o Fins (2 on TER) Fixed Pylon

Table III FILE INDEX OF F-111 WIND TUNNEL TESTS

NO.	FILE ID	ARRANGEMENT AT STATION 1	2	3	4	BOMB OR MISSILE	CONFIG. CODE	Λ (Degrees)	MACH NUMBER
1	7105	$^{o}\underset{o}{T}^{o}$	$^{o}\underset{o}{T}^{o}$	$^{o}\underset{o}{T}^{o}$ *	$^{o}\underset{o}{T}^{o}$ *	24 LAU 3A W/O NF	(37)	16, 26	.6, .8, .95
2	7901, 7902, 4306					24 LAU 3A W NF	(36)	16, 26	.25, .45, .6, .8, .95 (1.05, Λ=26°)
3	7107	$^{o}\underset{o}{T}^{o}$ *	$^{o}\underset{o}{T}^{o}$ *			12 LAU 3A W/O NF	(10)	26, 35, 50	.6, .8, 95, 1.05 (1.2, Λ=50°)
4	7701, 7702, 7703					12 LAU 3A W NF	(9)	26, 35, 50	.6, .8, .95, 1.05 (1.2, Λ=50°)
5	7207					12 M-117R	(7)	26, 35, 50	.6, .8, .95, 1.05 (1.2, Λ=50°)
6	7108	$^{o}\underset{o}{T}^{o}$ *	Pylon T			6 LAU 3A W/O NF	(10)	26, 35, 50	.6, .8, .95, 1.05 (1.2, Λ=50°)
7	7704, 7705, 7710					6 LAU 3A W NF	(9)	26, 35, 50	.6, .8, .95, 1.05 (1.2, Λ=50°)
8	7208					6 M-117R	(7)	26, 35, 50	.6, .8, .95, 1.05 (1.2, Λ=50°)
9	7101	$^{o}T^{o}$	$^{o}T^{o}$	$^{o}T^{o}$ *	$^{o}T^{o}$ *	16 BLU 1C/B W Fins	(33)	16, 26	.6, .8, .95 (1.05, Λ=26°)
10	7905, 7906, 4301					16 BLU 1C/B W Fins	(45)	16, 26	.25, .45, .6, .8, .95 (1.05, Λ=26°)

Note: * Instrumented Station (M= MER , T= TER)

Table III Continued

NO.	FILE ID	ARRANGEMENT AT STATION 1	2	3	4	BOMB OR MISSILE	CONFIG. CODE	Λ (Degrees)	MACH NUMBER
11	7811 7812 7813 7814 4307	o^*	o^*			4 M-118	(14)	26, 35, 50, 72.5	.25, .45, .6, .8, .95, 1.05 (1.20, 1.40, $\Lambda = 50^o$) (1.20, $\Lambda = 72.5^o$)
12	7807 7806 7808 7809					4 B43, QRC	(1)	26, 35, 50, 72.5	.6, .8, .95, 1.05 (1.2, 1.4, 1.6, $\Lambda = 50^o$, 72.5^o)
13	7801 7802	o^*	$\overset{T^o}{o}$			2 B43 & 4 AIM-9B	(1)	50, 72.5	1.4, 1.6
14	8001 8005					2 B43 & 4 AIM-9B	(1)	50, 72.5	1.80, 2.0, 2.20
15	7815 7816					2 B61 & 4 AIM-9B	(2)	50, 72.5	1,8, 2.0, 2.2
16	8009 8013					2 B61 & 4 AIM-9B	(2)	50, 72.5	1.8, 2.0, 2.2
17	7102	$o_T o$	$o_T o^*$	$o_T o^*$	Pylon T	12 BLU-1C/B W Fins	Sta 2 (6), Sta 3 (33)	26	.6, .8, .95, 1.05
18	4303	$o_T o$	$o_T o^*$	$o_T o^*$		12 BLU-1C/B W Fins	2 (6), 3 (33)	16, 26	.25, .45, .6
19	7103	$o_T o^*$	$o_T o^*$			8 BLU-1C/B W Fins	(6)	26, 35, 50	.6, .8, .95, 1.05 (1.2, $\Lambda = 50^o$;

Table III Continued

NO.	FILE NO.	ARRANGEMENT AT STATION 1	2	3	4	BOMB OR MISSILE	CONFIG. CODE	Λ (Degrees)	MACH NUMBER
20	4302	${}^{\circ}T^{\circ *}$	${}^{\circ}T^{\circ *}$	${}^{\circ}T^{\circ}$	${}^{\circ}T^{\circ}$	16 BLU-1C/B W/O Fins	(16)	26	.25, .45, .6
21	7104	${}^{\circ}T^{\circ *}$	Pylon T			4 BLU-1C/B W Fins	(6)	26, 35, 50	.6, .8, .95, 1.05
22	7106	${}^{\circ}\underset{\circ}{T}^{\circ}$	${}^{\circ}\underset{\circ}{T}^{\circ *}$	${}^{\circ}\underset{\circ}{T}^{\circ *}$	Pylon T	18 LAU-3A W/O NF	Sta 2 (10), Sta 3 (37)	26	.6, .8, .95, 1.05
23	7903	${}^{\circ}\underset{\circ}{T}^{\circ}$	${}^{\circ}\underset{\circ}{T}^{\circ *}$	${}^{\circ}\underset{\circ}{T}^{\circ *}$	${}^{\circ}\underset{\circ}{T}^{\circ}$	24 LAU-3A W NF	2 (9), 3 (36)	26	.6, .8, .95, 1.05
24	7202	${}^{\circ}\underset{\circ}{M}^{\circ}$	${}^{\circ}\underset{\circ}{M}^{\circ *}$	${}^{\circ}\underset{\circ}{T}^{\circ}$	${}^{\circ}\underset{\circ}{T}^{\circ}$	36 M-117R	(8)	26	.6, .8, .95, 1.05
25	7203	${}^{\circ}\underset{\circ}{M}^{\circ}$	${}^{\circ}\underset{\circ}{M}^{\circ *}$	${}^{\circ}\underset{\circ}{T}^{\circ}$	Pylon T	30 M-117R	(8)	26	.6, .8, .95, 1.05
26	7201	${}^{\circ}\underset{\circ}{M}^{\circ}$	${}^{\circ}\underset{\circ}{M}^{\circ}$	${}^{\circ}\underset{\circ}{T}^{\circ *}$	${}^{\circ}\underset{\circ}{T}^{\circ *}$	36 M-117R	(34)	16, 26	.6, .8, .95 (1.05, Λ=26°)
27	7204	${}^{\circ}\underset{\circ}{M}^{\circ}$	${}^{\circ}\underset{\circ}{M}^{\circ}$	${}^{\circ}\underset{\circ}{T}^{\circ *}$	Pylon T	30 M-117R	(34)	26	.6, .8, .95, 1.05
28	{8206 {7209	${}^{\circ}\underset{\circ}{M}^{\circ *}$	${}^{\circ}\underset{\circ}{M}^{\circ *}$			24 M-117R	(8)	35 26, 50	.6, .8, .95 .6, .8, .95, 1.05 (1.2, Λ=50°)
29	{7206 {7205	${}^{\circ}\underset{\circ}{M}^{\circ *}$	Pylon M			24 M-117R	(8)	26, 35 50	.6, .8, .95, 1.05 .6, .8, .95, 1.05, 1.2

Table III Continued

NO.	FILE ID	ARRANGEMENT AT STATION 1	2	3	4	BOMB OR MISSILE	CONFIG. CODE	Λ (Degrees)	MACH NUMBER
30	7401, 7405, 7409, 741?		$^{o}M^{o}_{o}$ *			12 M-117R	(8)	26, 35, 50, 72.5	.6, .8, .95, 1.05 (1.2, Λ=50°, 72.5°)
31	8601, 8602, 8603		M^{o} *	SD=20, 45		12 M-117R	(8)	26 SD=0, SD=20, SD=45	.6, .8, .95
	8604, 8605							50 SD=20, SD=45	.6, .8 .6, .8, .95, 1.05, 1.2
32	7210	$^{o}M^{o}_{o}$ *	$^{o}T^{o}_{J}$			12 M-117R, 6 LAU 3A W NF	(8)	26, 35, 50	.6, .8, .95, 1.05 (1.2, Λ=50°)
33	7211	$^{o}M^{o}_{o}$	$^{o}T^{o}_{o}$ *				(9)	26, 35, 50	.6, .8, .95, 1.05 (1.2, Λ=50°)
34	7414, 7419, 7420	$^{o}M^{o}_{o}$ *				12 M-117R	(8)	26, 35, 50	.6, .8, .95, 1.05 (1.2, Λ=50°)
35	7418, 7421	$^{o}M^{o}_{o}$ *				12 M-117R, QRC	(8)	26, 50	.6, .8, .95, 1.05 (1.2, Λ=50°)
36	7810, 7803, 7804, 7805	O*	Pylon			2 M-118	(14)	26, 35, 50, 72.5	.6, .8, .95, 1.05 (1.2, 1.4, Λ=72.5°)

Table III Continued

NO.	FILE ID	ARRANGEMENT AT STATION 1	2	3	4	BOMB OR MISSILE	CONFIG. CODE	Λ (Degrees)	MACH NUMBER
37	8117 8120 8201 8203	—	o*			2 M-118	(14)	26, 35, 50, 72.5	.6, .8, .95
38	7706 7707 7708 7709	Pylon M	oTo* o			6 LAU 3A W NF	(9)	26, 35, 50, 72.5	.6, .8, .95, 1.05 (1.2, Λ = 72.5°)
39	7109 7111	—	o*			2 TMU-28B	(3)	26, 35 50, 72.5	.6, .8, .95, 1.05 .6, .8, .95, 1.05, 1.2, 1.4, 1.6
40	8505 4304	—	o*	o*		4 TMU-28B	2 3 (3),(31)	16	.6, .8, .95 .25, .45, .6, .8, .95
41	7110 4304	—	o*	o*		4 TMU-28B	2 3 (3),(31)	26	.6, .8, .95, 1.05 .25, .45, .6, .8, .95, 1.05
42	7601 7605 7607	Mo* o	Mo* o			16 M-117R Slant 4 on MER	(12)	26, 35, 50	.6, .8, .95, 1.05 (1.2, Λ = 50°)
43	7602 7606 7608	Mo* o	Mo* o			16 M-117R Slant 4 on MER, QRC	(12)	26, 35, 50	.6, .8, .95, 1.05 (1.2, Λ = 50°)
44	7603 7604 7609	Mo* o	Pylon T			8 M-117R Slant 4 on MER	(12)	26 35, 50	.6, .8, .95, 1.05 (1.2, Λ = 50°)
45	7610 7611 7612 7613	—	oMo			8 M-117R Flat 4 on MER	(13)	26, 35, 50, 72.5	.6, .8, .95, 1.05 (1.2, Λ = 50°, 72.5°)

Table IV CDC 6600 PROCEDURE A7A PRINTOUT

```
GENERAL DYNAMICS           CONVAIR AEROSPACE DIVISION        FORT WORTH OPERATION
6600 PROCEDURE A7A            PROBLEM 176363-01              01/22/73    PAGE 0001

STORE   =   RLU1C/BF2T
MACH    =   6.0000E-01
CON NO  =   3.3000E+01
STA NO  =   3.0000E+00
FILEID  =   7.1010E+03
STYPE   =   1.0000E+00

- SWEEP   = 1.6000E+01

ALPHA     = -4.9639E+00-1.9518E+00 3.2129E-02 1.9891E+00 4.9950E+00 7.0865E+00 1.0028E+01 1.2004E+01 1.5053E+01 1.7035E+01
               2.0034E+01 2.2012E+01 2.4435E+01

CN        = -1.9834E+00-1.2377E+00-8.7787E-01-5.3255E-01-9.9533E-02 1.8068E-01 5.1335E-01 7.2351E-01 1.0391E+00 1.2480E+00
               1.5794E+00 1.8045E+00 2.2185E+00

- SWEEP   = 2.6000E+01

ALPHA     = -4.9911E+00-1.9315E+00-2.8800E-02 1.9959E+00 5.0562E+00 7.0046E+00 1.0034E+01 1.1961E+01 1.5031E+01 1.7028E+01
               2.0324E+01 2.2327E+01 2.5041E+01

CN        = -1.3553E+00-7.6783E-01-5.4649E-01-3.4155E-01-1.3675E-02 1.7724E-01 5.29[illegible] 7.2537E-01 1.0463E+00 1.2207E+00
               1.5139E+00 1.7303E+00 2.1535E+00
```

<u>Definitions</u>:

STORE - Instrumented Store

CON NO. - Configuration No. from Table II

STA NO. - Instrumented Pylon Station

FILE ID - Magnetic Tape Identification Table III

STYPE - 1.0, Store + Rack + Pylon Instrumented

2.0, Store + Rack Instrumented

FILEID = 7101.000 STA NO = 3.000 STORE =BLU1C/BF2T
MACH = .600 STYPE = 1.000

O- SWEEP = 16.000 □- SWEEP = 26.000

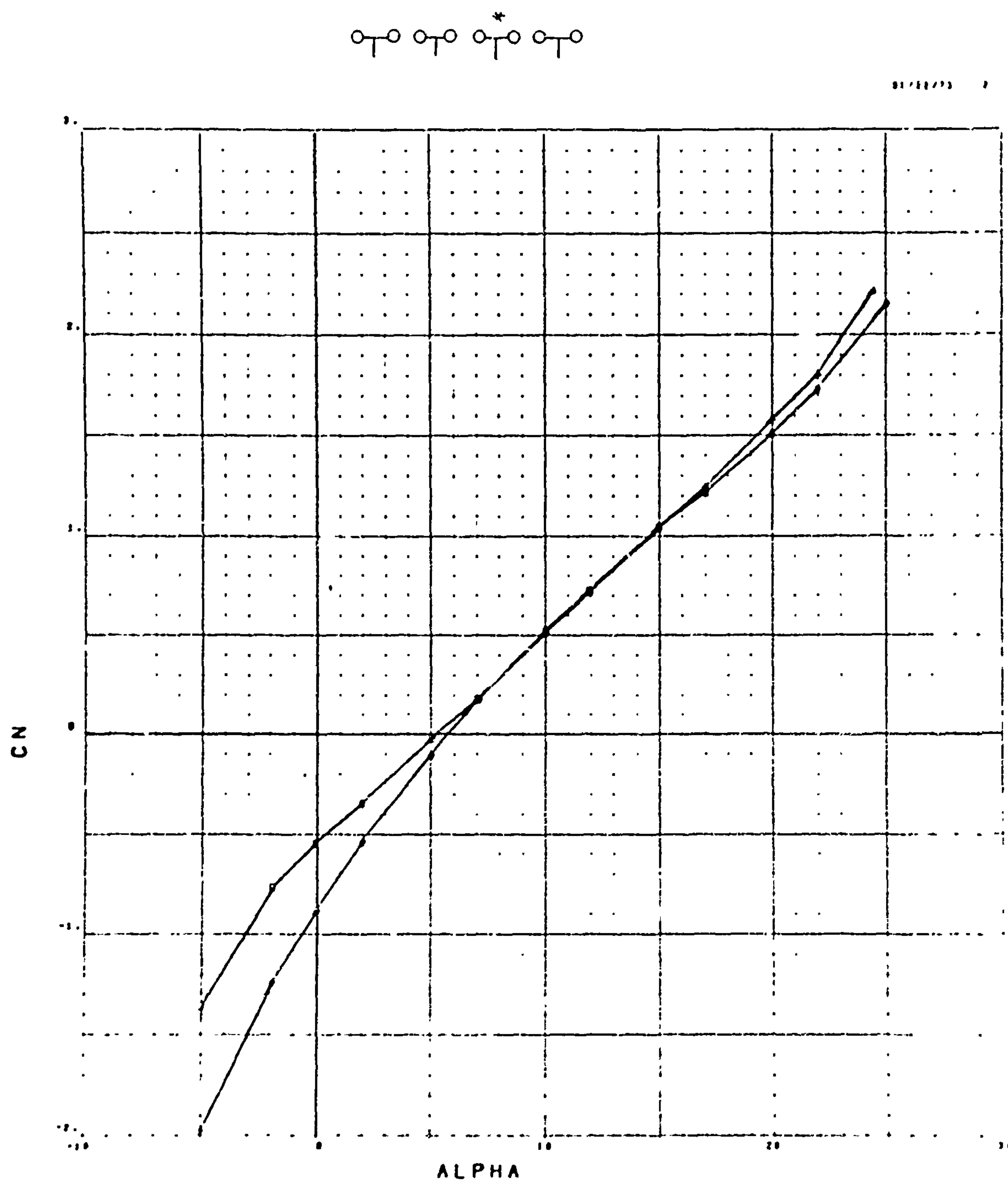


Figure 19 CDC 6600 PROCEDURE A7A PLOTTED DATA

SECTION 3

DEVELOPMENT OF CORRELATION TECHNIQUES

During the period of the study devoted to the development of techniques to correlate the store loads test data, two major tasks evolved: the selection of pertinent parameters on which to perform a correlation, and the selection of store arrangements among which a correlation could be made.

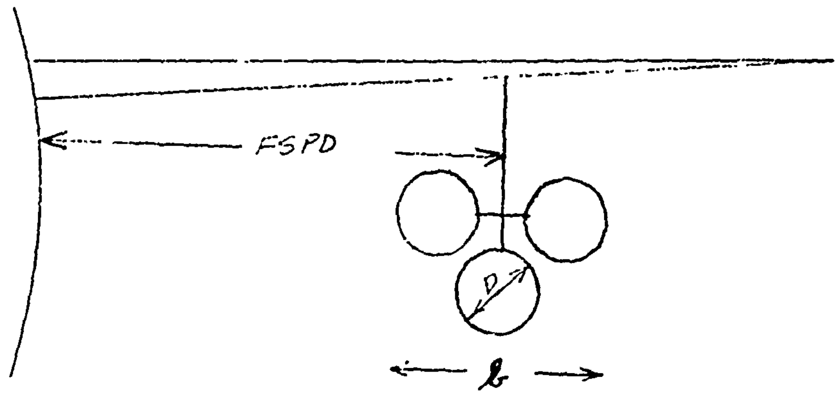
A background was first established by reviewing literature where tasks of a similar nature had already been attempted. The material contained in References 1 and 2 served as a convenient reference point since most of the work of recent years concerned with prediction of external store loads is reviewed in these documents. In addition, a paper prepared for the Navy (Reference 3) was reviewed. This paper is concerned with a correlation task, similar to the present task, in which an attempt is made to identify geometric parameters that could be used to establish a base for correlation of store aerodynamic loads data on complex store arrangements along the span of a wing. Such parameters as the side projected area of the total store plus pylon are utilized along with certain distances to evaluate the proximity to other stores, the fuselage, and the wing.

This initial survey contributed substantially to the selection of geometry parameters used in the study. In fact, the initial steps taken in the empirical correlations (Section 3.1) were directly influenced by the early investigations discussed above. The selected parameters are defined in Table V along with specific values pertaining to the airplane configuration. The geometries of the stores investigated are given in Figures 20 through 25

3.1 Empirical Analysis

During the initial phase of this part of the study, a substantial effort was devoted to the possibility of establishing a correlation of the experimental data through empirically derived geometry parameters.

TABLE V GEOMETRY DEFINITIONS



SA	=	Side Projected Area
FA	=	Frontal Area of Weapons + Rack + Pylon
PA	=	Planform Area of Weapons + Rack + Pylon
FSPD	=	Fuselage Side to C_L of Pylon Distance
AR_{LOAD}	=	$b^{\cdot 2}/PA$
$C_{N_{PA}}$	=	Normal Force Coefficient based on PA
ℓ	=	Overall Length of Load on Pylon (Does Not Include Pylon)
D	=	Diameter of Weapon
C	=	Wing Chord at Pylon Location
ΔX	=	Weapon Nose to Wing Leading Edge X-Distance
NFB	=	Number of Front Bombs
FR_{NOSE}	=	Fineness Ratio of Theoretical Nose on Blunt Weapons

Frontal Area	560.0 in^2
Planform Area	3704.0 in^2
Side Area	4976.0 in^2
Length "l"	182.0 in
Diameter "d"	24.1 in

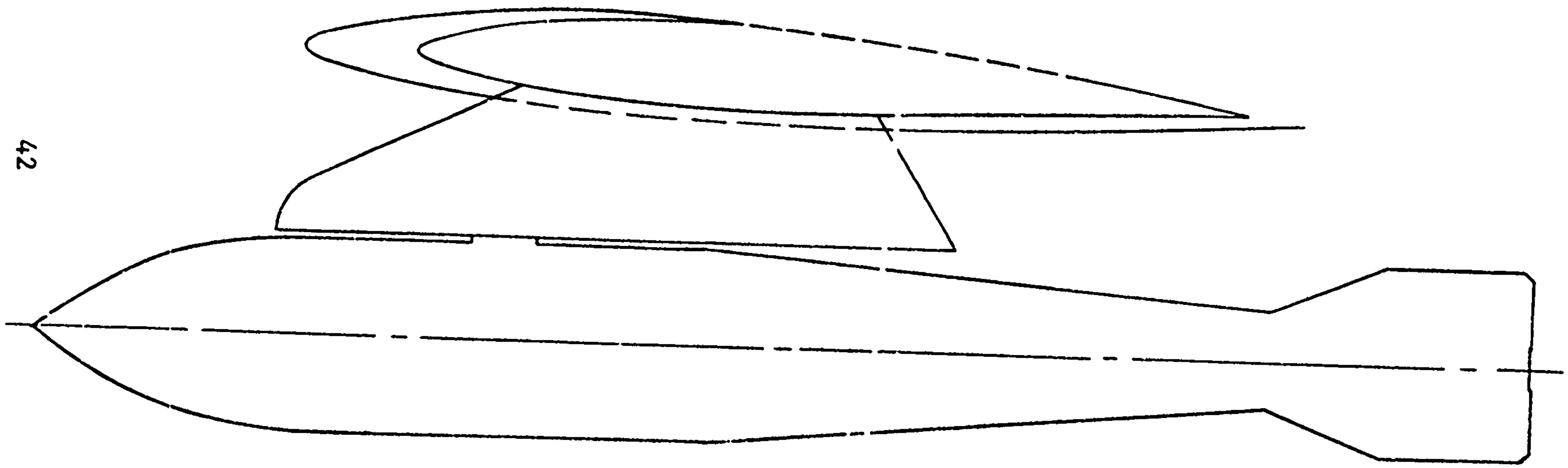


Figure 21 M-118 INSTALLATION

Frontal Area		760.0 in^2
Planform Area		5590.0 in^2
Side Area		3948.0 in^2
Length	"l"	143.5 in
Diameter	"d"	18.2 in

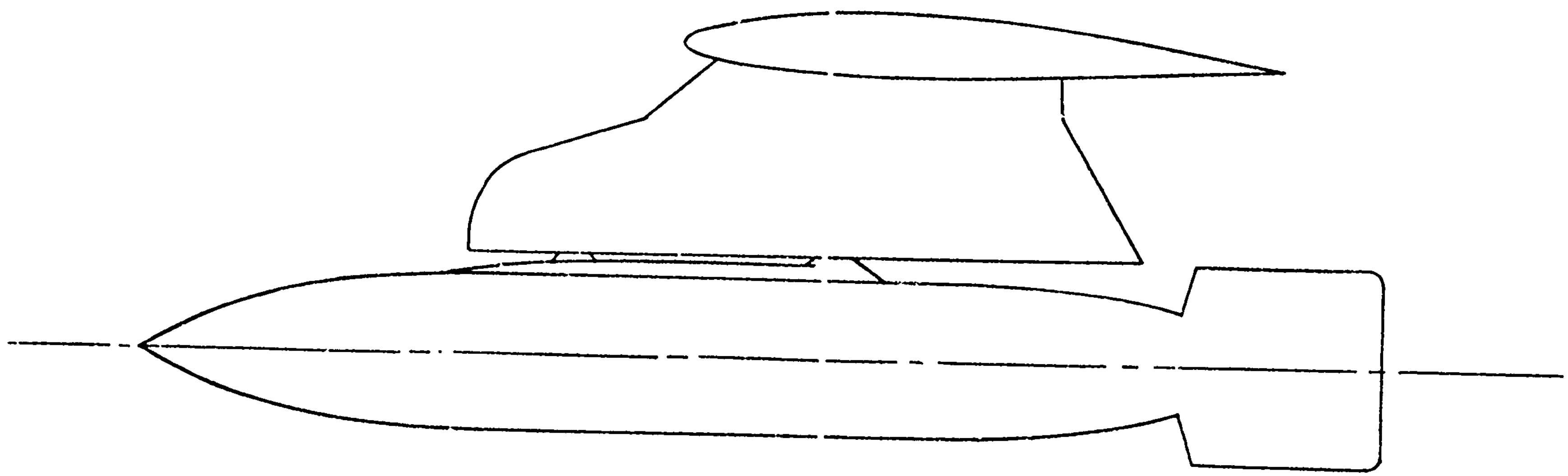


Figure 22 BLU-1C/B INSTALLATION

Frontal Area	497.6 in^2
Planform Area	3750.0 in2
Side Area	5106.0 in^2
Length "l"	180.0 in
Diameter 'd"	22.5 in

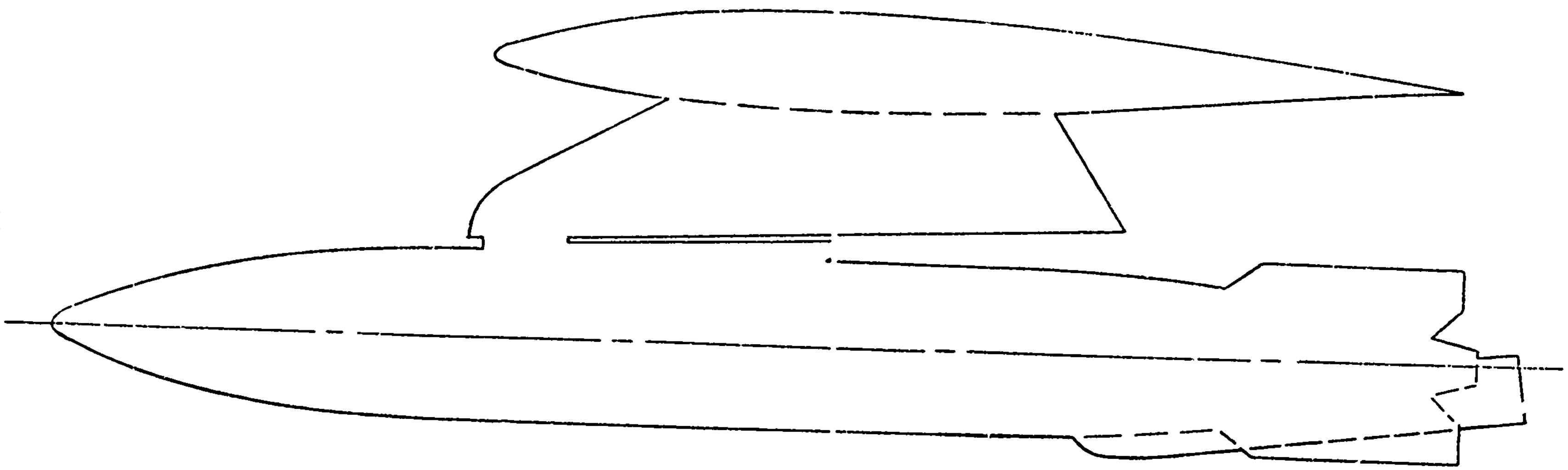


Figure 23 TMU-28B INSTALLATION

Frontal Area		840.0 in^2
Planform Area		2890.0 in^2
Side Area		3536.0 in^2
Length	"l"	79.0 in
Diameter	"d"	16.4 in

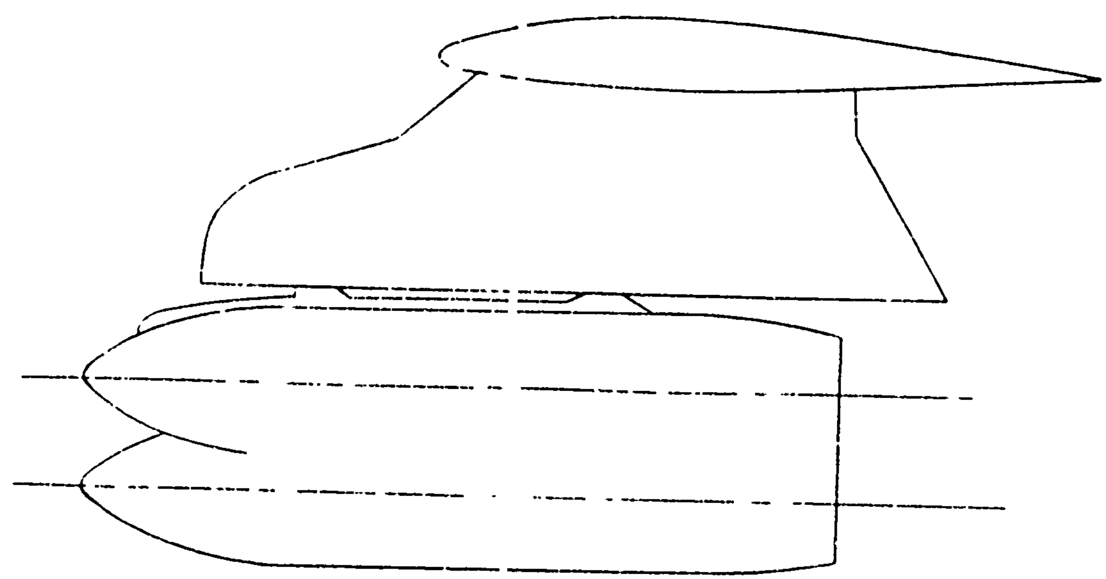


Figure 24 LAU-3/A INSTALLATION

Frontal Area	640.0 in^2
Planform Area	5276.0 in^2
Side Area	6700.0 in^2
Length "l"	85.5 in
Diameter "d"	16.5 in

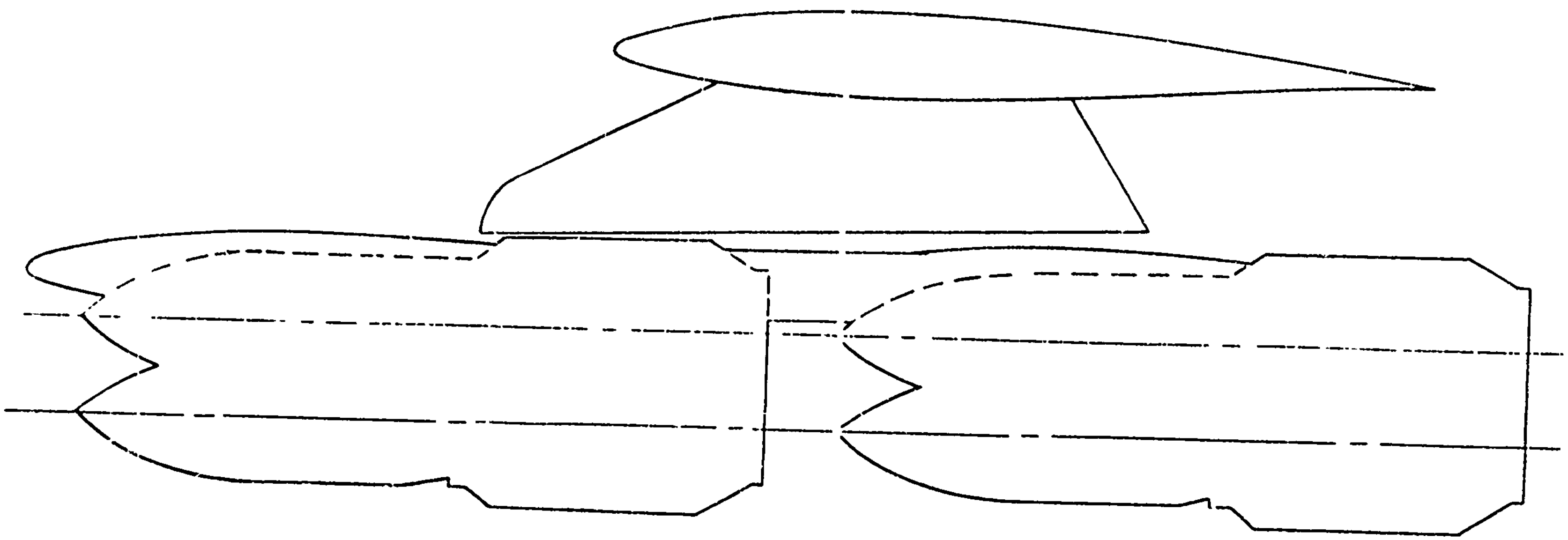


Figure 25 M-117R INSTALLATION

The first attempts were made on the normal force coefficient, C_N, for the configurations with a cluster of weapons at a single pylon station, with from one to four wing pylon stations occupied. The initial studies were conducted for a 26-degree wing sweep at a Mach number of 0.60 and a wing angle of attack of 26 degrees. The results are shown in Figure 26. In this figure, the normal force acting on the store-pylon is non-dimensionalized with respect to store planform area rather than airplane wing planform area as was done when the data were first received from the wind tunnel. It was logical to assume that the projected area normal to the vertical velocity vector would be important in establishing the magnitude of the normal load. It was decided that this area would be defined as the projected area presented on a horizontal plane passing through the centerline of the weapon cluster. In addition to the projected area, the fineness ratio or some function of the ratio of frontal area to projected area was felt to be important based on surveys of the literature in which methods of calculating the lift effectiveness of bodies of revolution are surveyed (Reference 4). Curves were then faired through similar groups of data. In this case the curves were faired through a group which had the same bomb at all pylon stations and in which the outermost pylon station loads were measured.

An additional step was taken to establish a shape-factor effect on the correlation of the data. This shape factor was selected as the square of the number of front bombs divided into the normal load coefficient $(C_{N_{PA}}/(NFB)^2)$ plotted against the same correlating parameter as used in the plots of Figure 26. Again a set of curves was faired through the data for loadings with increasing number of pylon stations loaded and measurements made on the outermost station (Figure 27). The second overlapping set of curves, represented by the dashed curves, was added. The lowest set of data, corresponding to the LAU-3A weapons, was connected to account for fineness ratio of the nose.

In the third and final attempt to increase the number of configurations which would fall on faired areas, an additional geometric correlating parameter was employed. In this third phase of the empirical studies, the aspect ratio of the pylon-store configuration was defined and was multiplied by the value of the normal load coefficient divided by the shape factor-number of front bombs squared. This value was then plotted against the term (PA/FA) x FSPD,

as shown in Figures 28, 29, 30, and 31. The Figure 28 plot is for an angle of attack of 20 degrees. In Figures 29, 30, and 31, the empirical correlation studies were expanded to include the full range of angles of attack from +20 to -5 degrees. Again, curves were faired through data points for the same weapon mounted at all pylon stations (solid curve), and an overlapping set of curves was faired through the data points for different weapons but with the same number of pylon stations occupied (dashed curves). A visual inspection of the curves at the different angles of attack established that the pattern was the same at all angles of attack, with the pattern rotating as the angle of attack changed.

A substantial number of data points did not lie on the curves constructed to this point, but the fact that a pattern of curves was beginning to emerge indicated that if a sufficient number of geometric parameters could be identified, correlation of the data for a greater variety of store configurations could be achieved. It was apparent at this point that the trial and error method of achieving correlation of data was successful in identifying pertinent first-order geometric correlating parameters. This method, however, would need to be automated so that the very large amount of data available could be processed and the wind tunnel data could be simultaneously tested against the number of geometric correlating variables that were obviously important.

At this point in the program, these initial efforts to achieve correlation through hand or empirical studies were essentially stopped.

3.2 Numerical Analysis

As stated above, it was recognized that the amount of data that would have to be considered for a correlation study would make it impossible to accomplish the task by hand methods. Substantial experience had already been accumulated by other investigators, where large amounts of wind tunnel data were available and it was required to develop generalized prediction techniques based on an empirical correlation of the experimental results. One such study, reported in Reference 5, derived a prediction technique for drag-due-to-lift of generalized aircraft configurations.

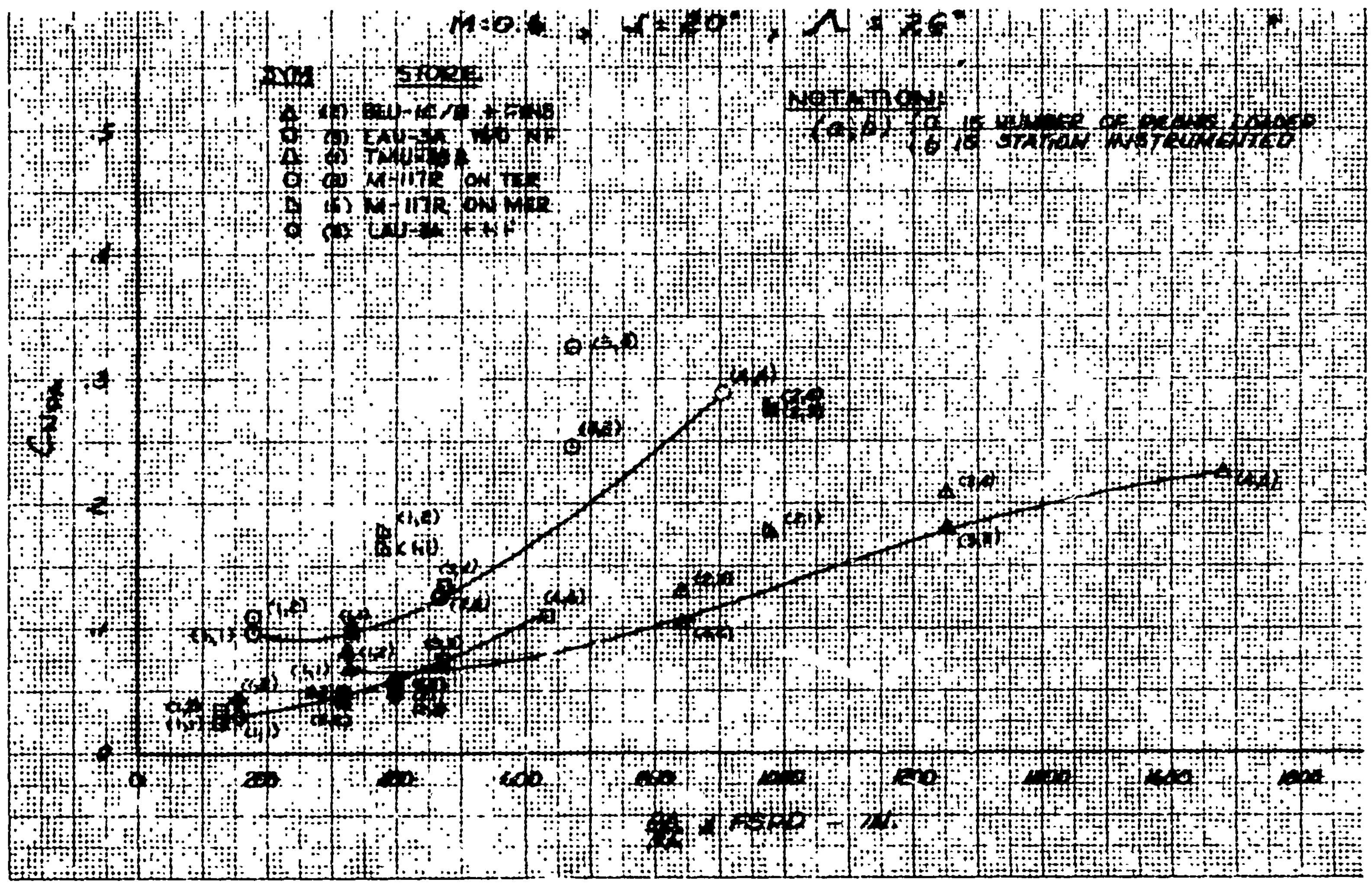


Figure 26 CORRELATION OF NORMAL FORCE FOR SELECT LOADINGS

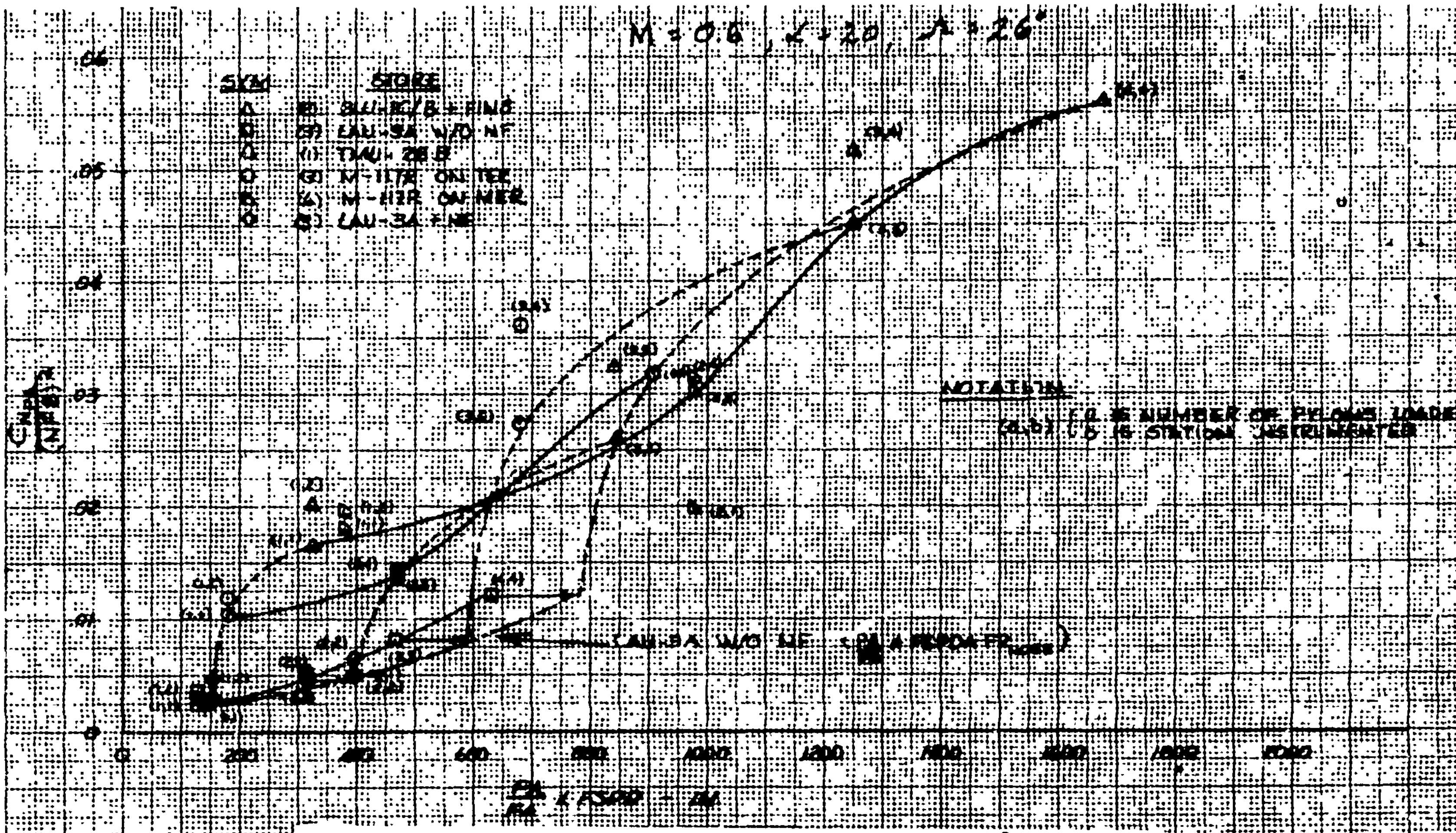


Figure 27 CORRELATION OF NORMAL FORCE/(NFB)^2, α = 20°

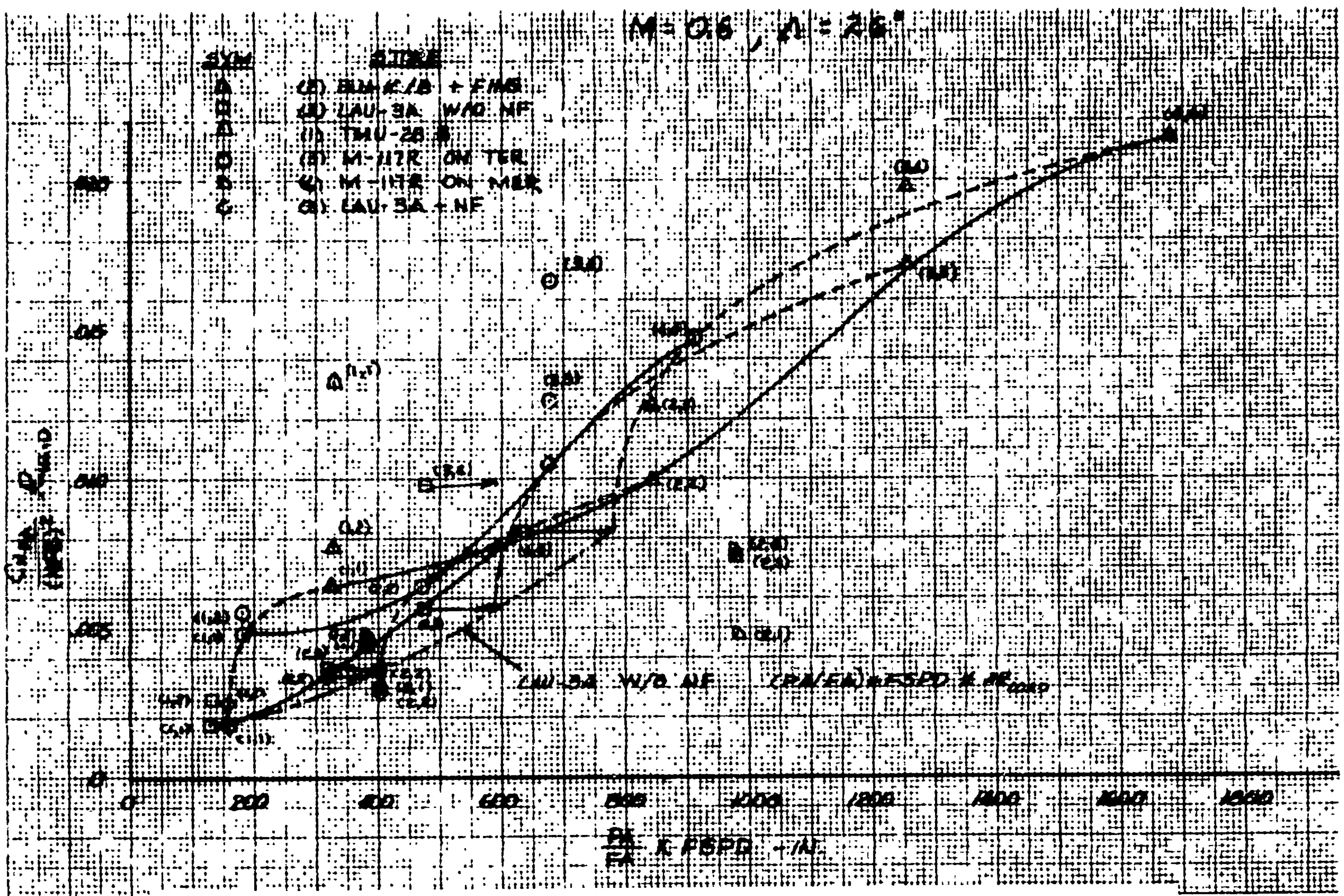


Figure 28 CORRELATION OF NORMAL FORCE/$(NFB)^2/AR_{LOAD}$, $\alpha = 20^{o}$

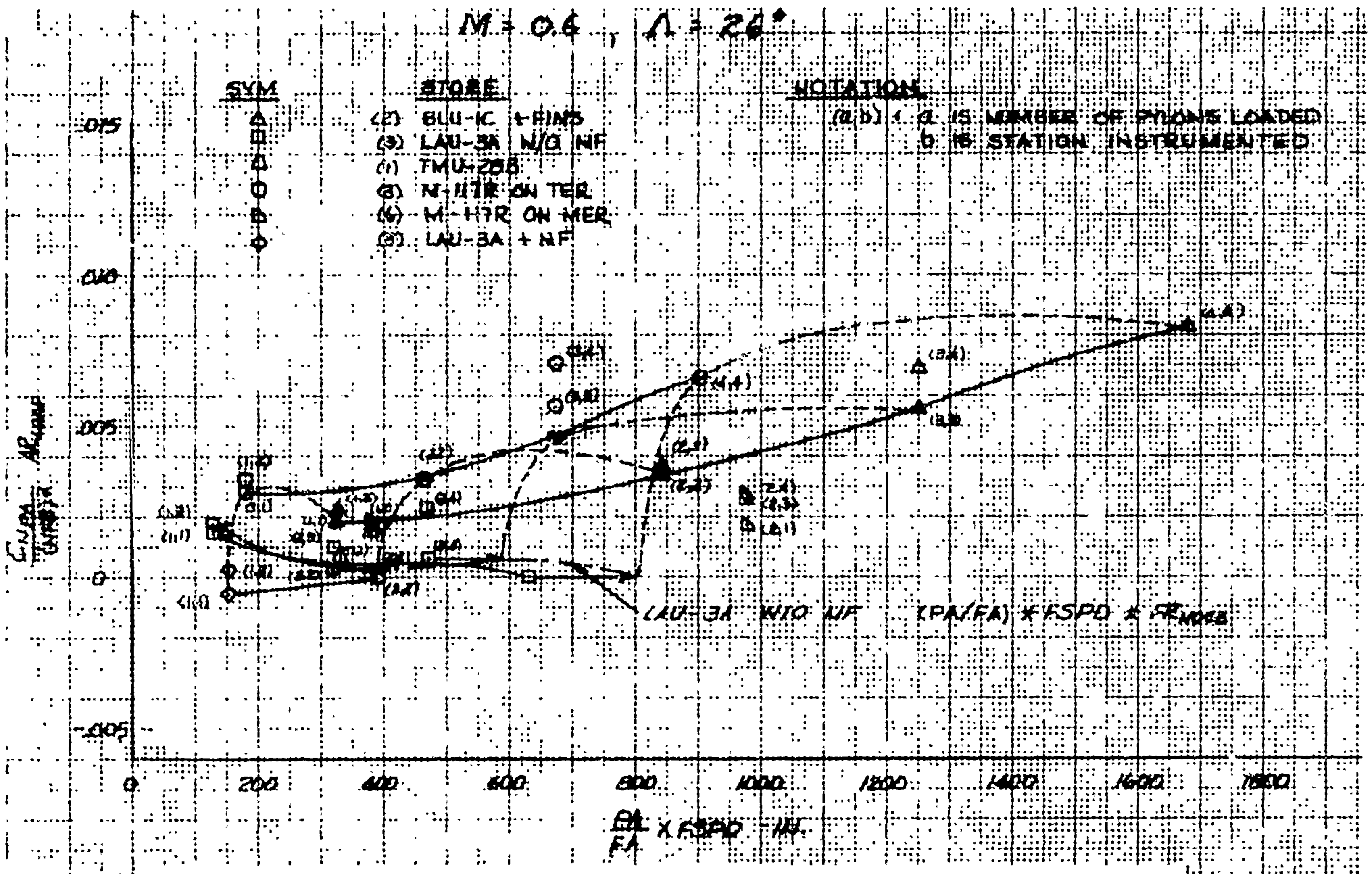


Figure 29 CORRELATION OF NORMAL FORCE/$(NFB)^2/AR_{LOAD}$, $\alpha = 10^{\circ}$

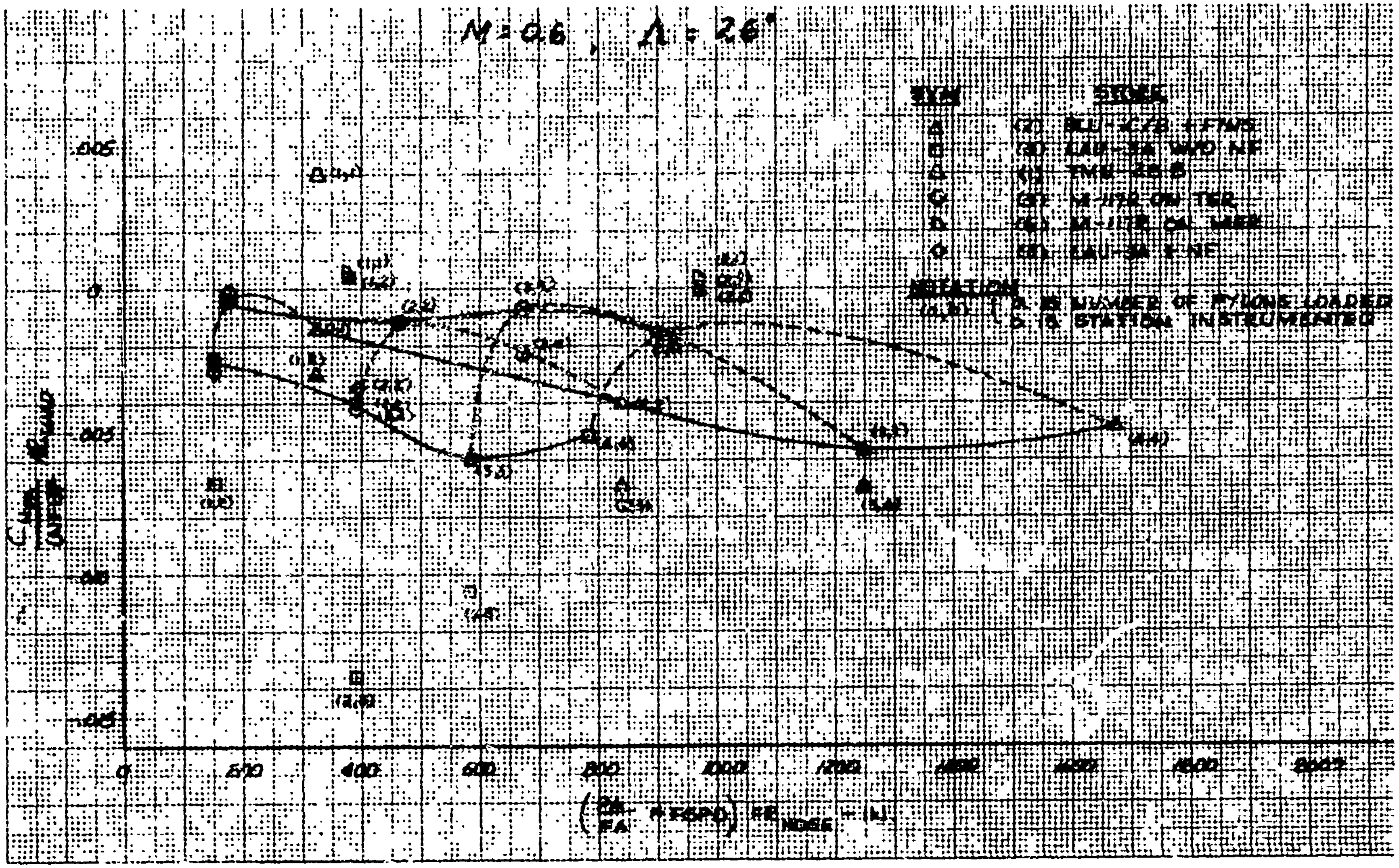


Figure 30 CORRELATION OF NORMAL FORCE/$(NFB)^2$/AR_{LOAD}, $\alpha = 0°$

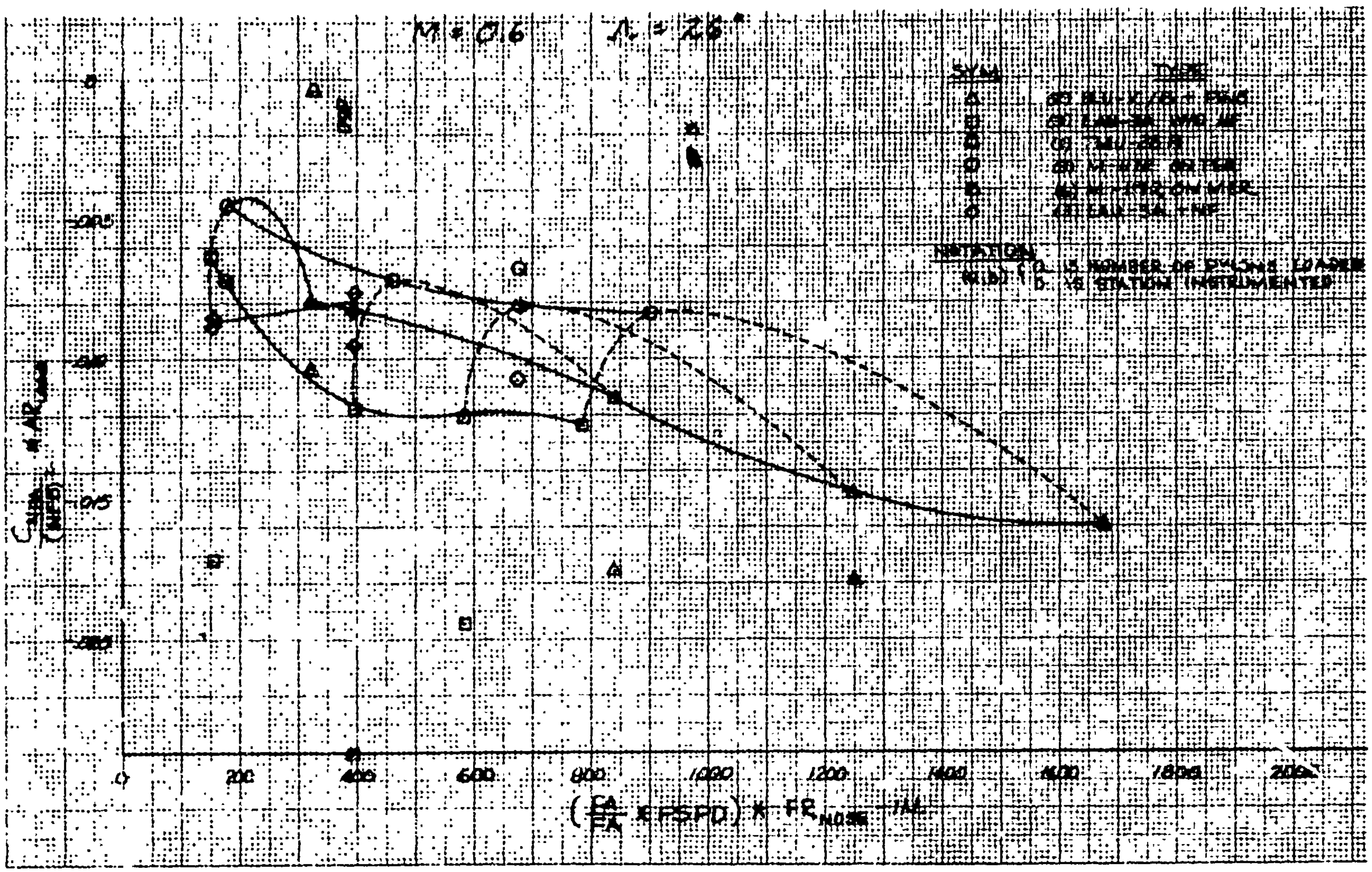


Figure 31 CORRELATION OF NORMAL FORCE/$(NFB)^2/AR_{LOAD}$, $\alpha = -5^{\circ}$

In the Reference 5 study, statistical methods were used to establish a linear relationship between the aerodynamic parameters under investigation and pertinent geometry definitions for the corresponding wing-body configurations. In the determination of the lift and drag force coefficients, a data analysis was conducted at specific Mach numbers and specific angles of attack. The output of this analysis was an equation that would allow specific geometry inputs to be evaluated to predict the lift and drag coefficient at a specific angle of attack over a substantial range of Mach numbers. In general, the results of this program were satisfactory.

An additional study involving the use of statistical mathematical methods to develop generalized prediction techniques for the wing lift coefficient as a function of wing planform geometry is reported in Reference 6. The results of these studies were incorporated into computerized routines that supply design loads for initial studies of aircraft configurations during the preliminary design phase.

The use of mathematical statistical methods for correlation of experimental data has produced varied opinions as to the value of this type of approach. In general, statistical methods will produce correlation of experimental data resulting in equations containing correlating parameters in a particular format. The format of the statistical methods will not agree with anticipated results developed from a background of empirical or analytical predictions and for this reason the use of statistical methods will be most valuable where large amounts of data have been accumulated and little or no success has been achieved with other analysis methods.

From all of the cases reviewed it seemed that the best results could be obtained by first obtaining empirical correlations on a limited number of configurations to establish data trends and pertinent geometric parameters. With these initial studies as a background the mathematical regression analysis techniques could then be utilized to derive analytical curve fits through data points for a greatly expanded variety of configurations.

The mathematical techniques established to achieve the correlations for the aerodynamic forces and moments acting on various external stores arrangements are described and discussed in the following subsections. The results of the

empirical studies (Section 3.1) were carried into the mathematical studies. It is noted that the first-order-geometric correlating parameters were established during the early empirical studies. The second-order geometric correlating parameters were established from the statistical analysis discussed in the following subsections.

3.2.1 Weighted Regression Analysis Procedure (WRAP)

The equations for correlating the forces and moments with various selected parameters were obtained by a weighted regression analysis procedure (WRAP), designated CDC 6600 Procedure A2E (Reference 7). This procedure performs multiple linear regression analysis on 80 or less independent variables and 25 or less dependent variables. The statistical techniques used in WRAP result in appropriate multipliers for each independent variable to best fit the test data (dependent variables). A description of the statistical methods used in the WRAP program are contained in Reference 8 and 9 and a general description of the procedure is presented below.

The mathematical model for regression analysis may be given in matrix notation as:

$$Y = XB + \Omega \tag{1}$$

where Y is an n x 1 vector of observations on what is usually referred to as the dependent variable. X is an n x p (n > p) matrix of observations on the p independent variables. B is (p x 1) and represents the true but unknown coefficients which connect Y and X. Ω is n x 1, a vector of random errors with mean zero and constant variance σ^2. When this condition of constant variance is not met, each of the n observations must be given a weight inversely proportional to its individual variance, hence the term "weighted regression analysis". The WRAP procedure was written with the option of using variable weights when required by the problem being studied.

It can be shown (see pp. 54 and 55 of Reference 9) that the least-squares solution of Equation 1, given by

$$\hat{B} = (X'X)^{-1}X'Y \tag{2}$$

where $\hat{B}$, an estimate of B and X' is the transposed matrix of X, is the "best, linear, unbiased" solution of Equation 1.

The WRAP procedure includes an intuitively appealing method of selecting the (most) significant subset of the independent variables. The weighted regression analysis program will handle up to 80 independent variables and 25 dependent variables. An interpretive system is included that allows the user almost complete flexibility in transforming, combining, moving, and coding the input data.

The method used to pick the most significant subset of independent variables for each dependent variable consists of first performing the regression analysis on the entire set of p independent variables. Then for each variable in the analysis the statistic

$$\frac{b_i{}^2}{c_{ii}} \tag{3}$$

is computed, where b_i is the regression coefficient giving the relationship between the $\underline{ith}$ independent variable and the dependent variable and c_{ii} is the $\underline{ith}$ diagonal element of $(X'X)^{-1}$. This statistic gives the reduction in the regression sum of squares when X_i is deleted from the analysis.

Next, the minimum of $b_i{}^2/c_{ii}$ is obtained. This value is divided by the error sum of squares at that point, and this ratio has an F distribution. This value of F is tested against either a value of F or a probability level input to the procedure. (See References 8, 9, and 10)

If it is determined that this minimum sum of squares is significant, the deletion process is discontinued. Otherwise, X_i is deleted, and the inverse matrix is adjusted for the deletion.

Since the method given above for selecting the optimum subset of variables is equivalent to partially reinverting the X'X matrix, it is essential to include a check on the accuracy of the inverse. It should be pointed out that all operations are carried out on the correlation matrix which has all elements between ± 1. The basic inversion routine used throws out any variables that would cause singularity. After the correlation matrix is inverted, the norm of $(I - RB_0)$ is computed, where I is the p x p identity

matrix, R is the correlation matrix, and B_0 is the computed estimate of R^{-1}. The norm used is defined by

$$N(A) = \sqrt{\sum_i \sum_j a_{ij}^2} \qquad (4)$$

If this norm does not meet the specified requirements, an option is available to use Hotelling's method (Reference 10) to obtain a better estimate of the inverse. This is an iterative technique, where the ith estimate of the inverse is given by

$$B_i = B_{i-1}(2I - RB_{i-1}) \qquad (5)$$

If the norm mentioned above is less than 1.0, convergence to the true inverse is assumed (in theory). Actually, the degree of convergence is restricted by the use of floating-point arithmetic. In a limited number of tests, the indication is that the norm cannot be expected to get much smaller than $p \times 10^{-6}$.

The matrix inversion technique used in WRAP is an adaptation of the algorithm given by Efroymson (Reference 11). In WRAP, the technique is normally to proceed through the inversion process from left to right, inverting the rows and columns in 1, 3, 3, ... p order, unless a particular row (column) would cause singularity, in which event that row and column are left out of the inverted matrix and all subsequent regression analyses.

An option is included in WRAP which will cause the order of inversion to be determined at each step by selection of the largest diagonal element not yet included in the inverted matrix. This sometimes gives a better regression fit with fewer variables.

3.2.2 Application of Mathematical Correlations

The use of mathematical regression techniques does not permit a totally mechanical approach to the problem of arriving at geometric parameters which are pertinent to the objective of obtaining correlation with the force and moment coefficient data. In fact, a considerable amount of trial

and error effort went into the choice of the geometric parameters that were ultimately used in the formulation of the External Stores Prediction Handbook (Appendix II).

Some of the background work that went into the final choice of geometric parameters is discussed here. It is not possible to define every step that was taken in this interface process since a good many false starts were encountered that were not carried through to a final conclusion. The discussion is primarily intended to show that mathematical techniques had to be utilized in conjunction with considerable judgment in order to arrive at a proper correlation of data.

As stated in the previous subsections, the knowledge gained from the empirical studies was carried forward into the regression studies. In the initial trials with the regression analysis program, only the normal force coefficient, C_N was used. As explained earlier, this coefficient was non-dimensionalized with respect to the total weapon-rack-installation planform area. The value $C_{N_{PA}}/(NFB)^2/AR$ was then computed, and the term SA/FA/FSPD was used as one of the geometric correlating terms in all subsequent studies.

In utilization of the regression program, it was found that a comparison plot of the actual dependent variable against the calculated value produced from the regression program provides a ready visual check on the success of the final equation developed. In Figures 32, 33, and 34, the results of an investigation to obtain a correlation for the effects of angle of attack at a constant Mach number of 0.60 are shown, Three different functions of angle of attack were inserted as independent variables: α, α^2, and α^3. Results for three different levels of probability were plotted, and it can be seen that an unacceptable degree of scatter resulted in all cases.

It must be pointed out that one of the most disconcerting results noted in the use of mathematical regression procedures occurred with angle of attack, i.e., the result of changing the probability value resulted in equations having different geometric correlating parameters. In the case of the angle-of-attack study, an increase in probability produced equations with fewer geometric parameters. This is of course a characteristic of statistical regression analysis and causes considerable difficulty in achieving meaningful geometric correlating parameters with experimental results. Trial and error seem to be the only means of achieving successful use of regression studies as a means of correla-

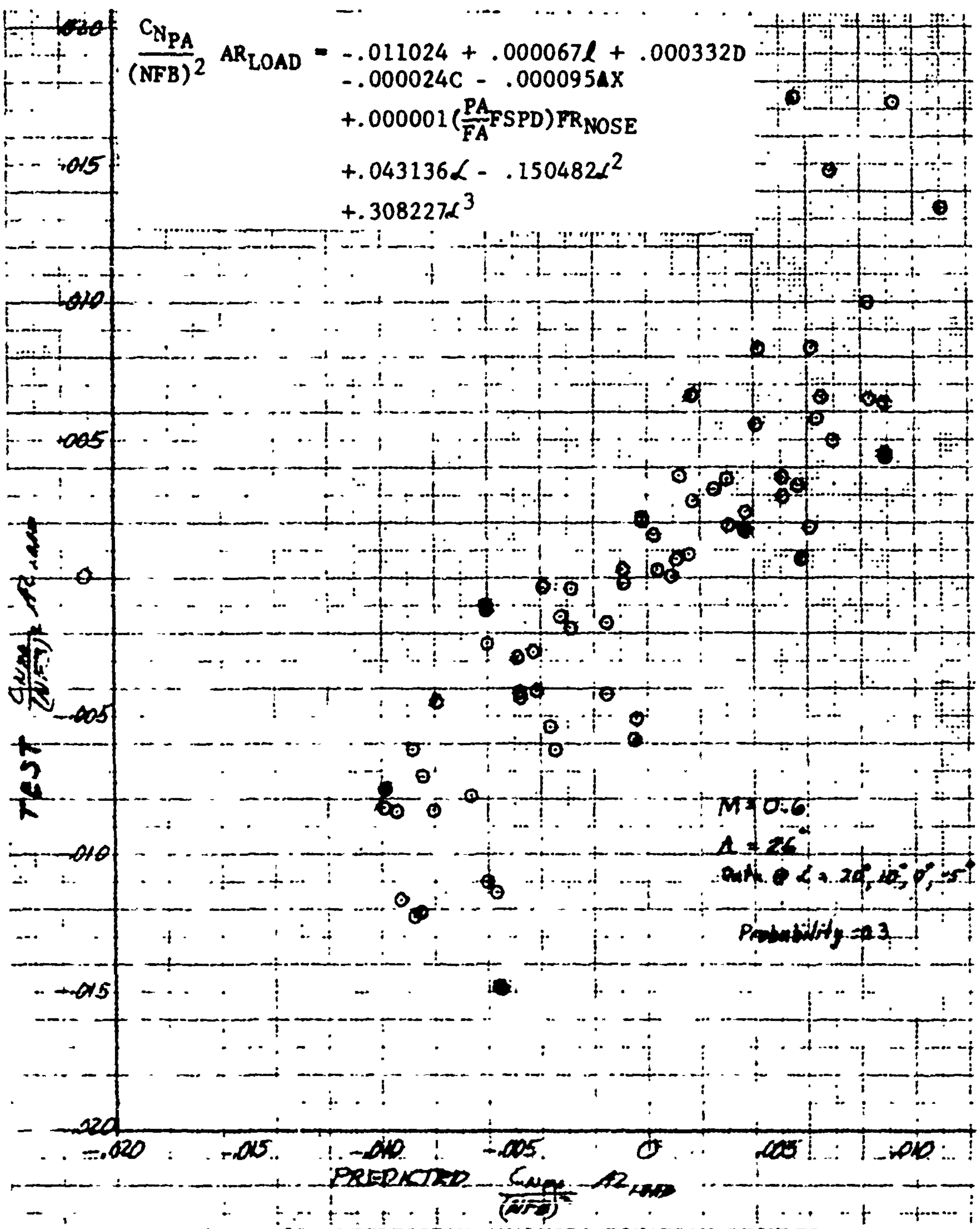


Figure 32 REGRESSION ANALYSIS EQUATION RESULTS COMPARED TO TEST DATA (PROBABILITY = 0.3)

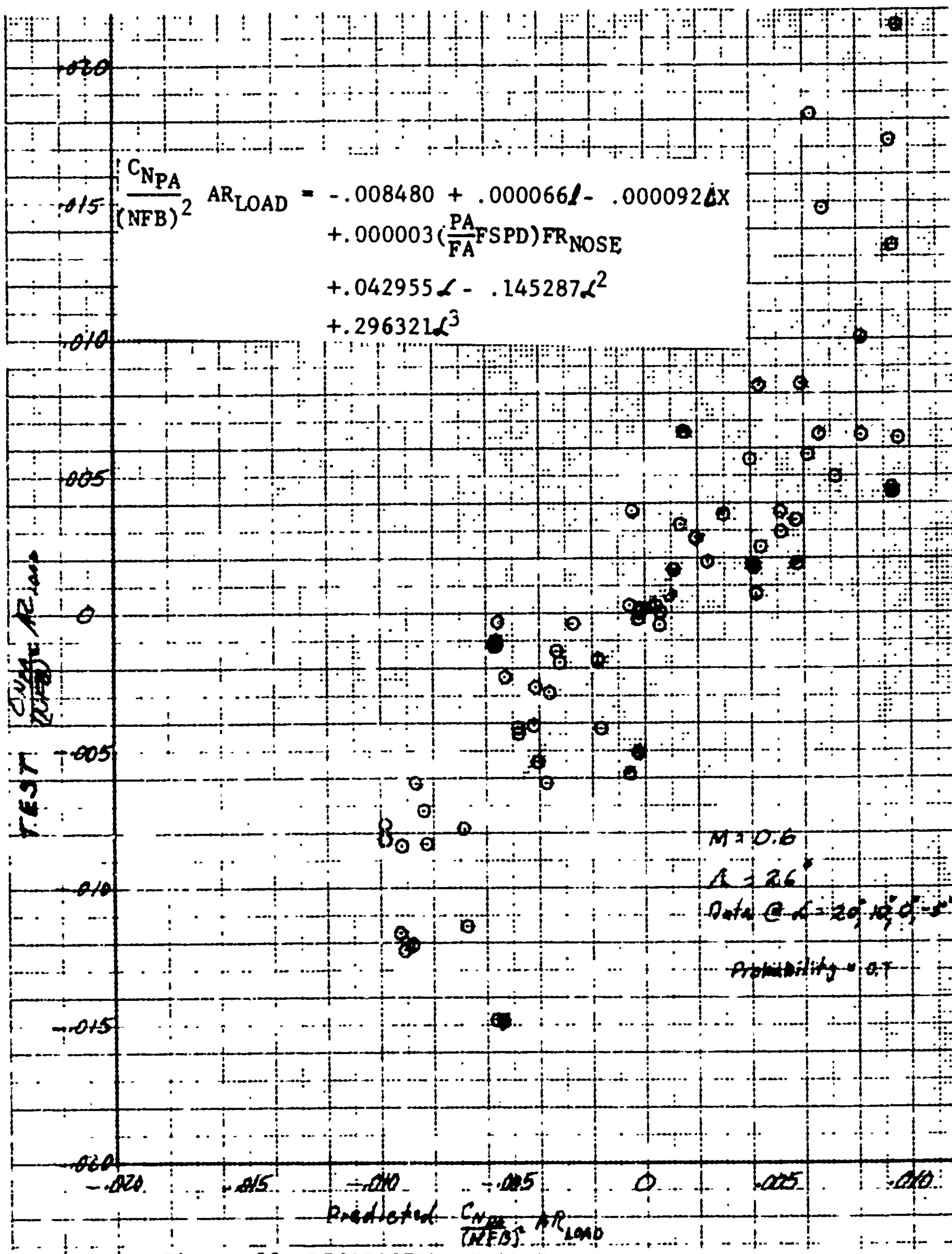


Figure 33 REGRESSION ANALYSIS EQUATION RESULTS COMPARED TO TEST DATA (PROBABILITY = 0.7)

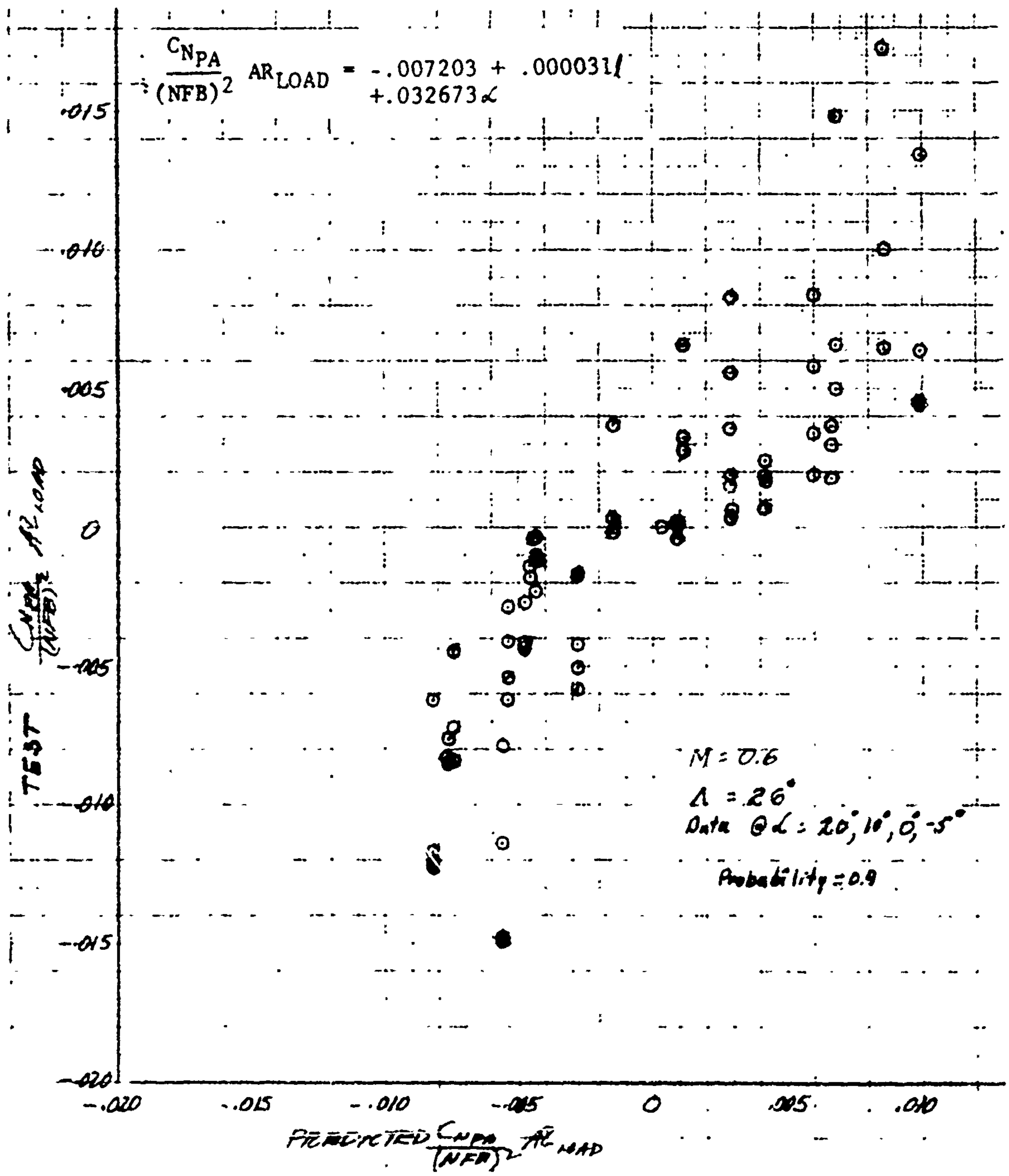


Figure 34 REGRESSION ANALYSIS EQUATION RESULTS COMPARED TO TEST DATA (PROBABILITY = 0.9)

tion of experimental data. It was decided, however, that the use of regression analysis would be continued in this study as the only practical means of correlating the large mass of store loads data.

From these studies, combined with visual inspection of the plotted results of computer procedure A7A, it was felt that the large amount of scatter was due to the large variation in the magnitude of the normal load coefficient. It was decided that some initial screening of the data would be necessary before a realistic start at data correlation would be attempted. With this in mind, data at a constant angle of attack was utilized in the correlations for the rest of the program.

Visual inspection of plotted A7A results demonstrated that variations with wing-sweep angle could possibly be accomodated in the same correlation study. Since variations with wing sweep were to be considered, it was necessary to establish some pertinent geometry parameters. One of these, of course, was wing-sweep angle expressed in degrees. Other geometry parameters considered to be pertinent were the distance of the nose of the weapons in front of the wing, Δx, and the distance of the pylon from the side of the fuselage, FSPD.

Selection of the parameter Δx was based on other investigations, such as that reported in Reference 12. In that investigation, the upwash angle of the flow varied substantially for various positions in front of the leading edge of a wing. The actual store angle of attack and, consequently, the normal load would then be a function of the distance the store extends into the upwash field in front of the wing.

From investigations such as that reported in Reference 13, it was felt that local flow characteristics around the store-pylon configuration would change, resulting in changes in normal load as the proximity with other stores changed. Since on the F-111 model the distance between the various pylon stations and the fuselage is a function of wing sweep, only one lateral distance was used to express this relationship. It was recognized at this point that there was some redundancy insofar as correlation was concerned since both Δx and FSPD are a function of wing sweep. The correlation under the regression analysis program was conducted, however, with these parameters. The results are shown in Figure 35.

It is obvious that a substantial improvement was obtained in reducing the amount of data scatter between the actual experimental data and the predictions based on the equation.

In a further attempt to improve the correlation, the wing-sweep angle was eliminated as a geometric variable. In addition, the term $D\Delta Y$ was changed to ΔY, and the term $D\Delta Z$ was eliminated. The results of these changes are shown in Figures 36 through 39 for constant angle of attack (each plot) and a constant Mach number of 0.60. It may be observed that the correlations were becoming more and more successful. This phase of the regression study was expanded to include higher Mach numbers; results at Mach 0.80 for angles of attack of 10 degrees and 20 degrees are shown in Figures 40 and 41, respectively.

The next phase of the study involved correlations combining data for a range of wing sweep and for Mach number variations. The initial results for the normal force coefficient are shown in Figure 42 for an angle of attack of 20 degrees. This investigation was conducted for a range of Mach numbers from 0.60 to 0.95 and included data for wing sweeps of from 16 to 72.5 degrees. The results of the correlations obtained with the regression analysis technique again eliminated the term Δy; however, there was some redundancy in the study since the term Δx is also a function of wing-sweep angle.

In the study to establish the feasibility of incorporating data for a range of Mach numbers in the same correlation study, two terms were first tried. These terms were M and M^2. In later studies, only the M^2 term was used, and the correlations were equally as good.

A complete study of the normal force coefficient for the outermost pylon position was now attempted. The results of these correlations are presented in Appendix I and discussed in the next section (Section 4). The data are shown at store angles of attack of -9, -4, +6, and +16 degrees for a sideslip angle of zero degrees, and at store angles of sideslip of -10 and +10 degrees at an angle of attack of 6 degrees.

As an aid in future correlations, the study was divided into major categories of external store geometry. This essentially reduced the number of configuration geometries that were considered during any one attempt to utilize the mathematical regression techniques. The major classifications of stores as defined in the remainder of this report are:

Weapons Cluster + Rack + Pylon

Weapons Cluster + Rack

Single Weapon + Rack + Pylon

Single Weapon + Rack

As described in Section 2.1, testing of the F-111 model was conducted such that store aerodynamic loads data were taken on the left wing for the store plus rack plus pylon and, at the same time, on the right wing for the store plus rack. This model capability allowed analysis to be conducted at two points on each major classification of weapon-pylon configuration.

$$\alpha = 20^{\circ}$$

$$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$$

$$M = 0.60$$

$$\frac{C_{N_{PA}}}{(NFB)^2} AR = -.028352 + .002164D - .000120C$$
$$-.000028\Delta X - .000152D\Delta Y_1$$
$$+.000167D\Delta Z_1 + .000005 \frac{PA}{FA} \times FSPD$$
$$+.000201\Lambda_{LE}$$

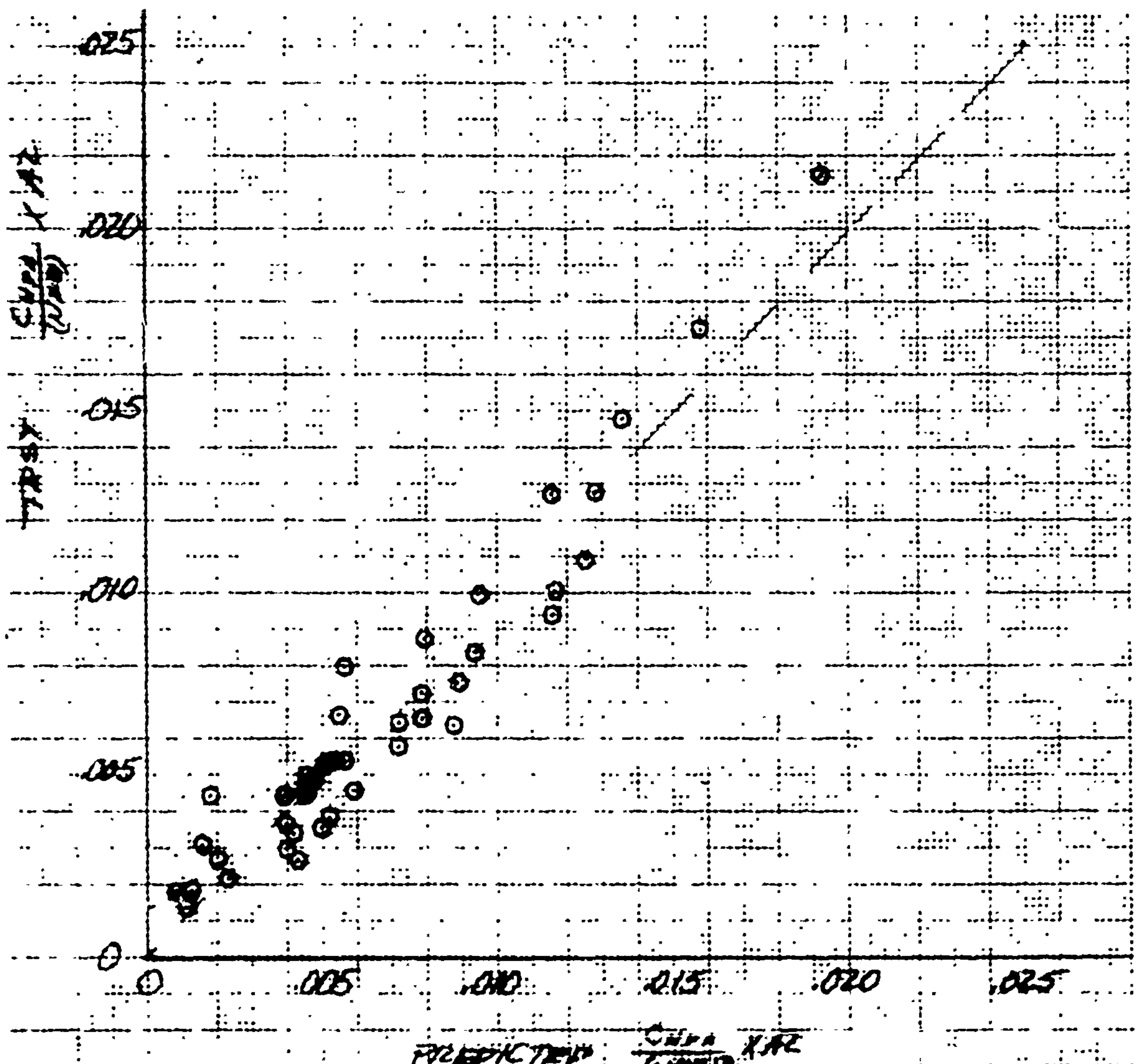


Figure 35 Regression Analysis Including Wing Sweep Angle As A Correlating Parameter

$\alpha = 20^{\circ}$

M = 0.60

$$\frac{C_{NPA}}{(NFB)^2} AR = .04724 + .00018504\ell - .003262D$$
$$-.00004155C - .000180\Delta X$$
$$+.00001308 \frac{PA}{FA} \times FSPD$$

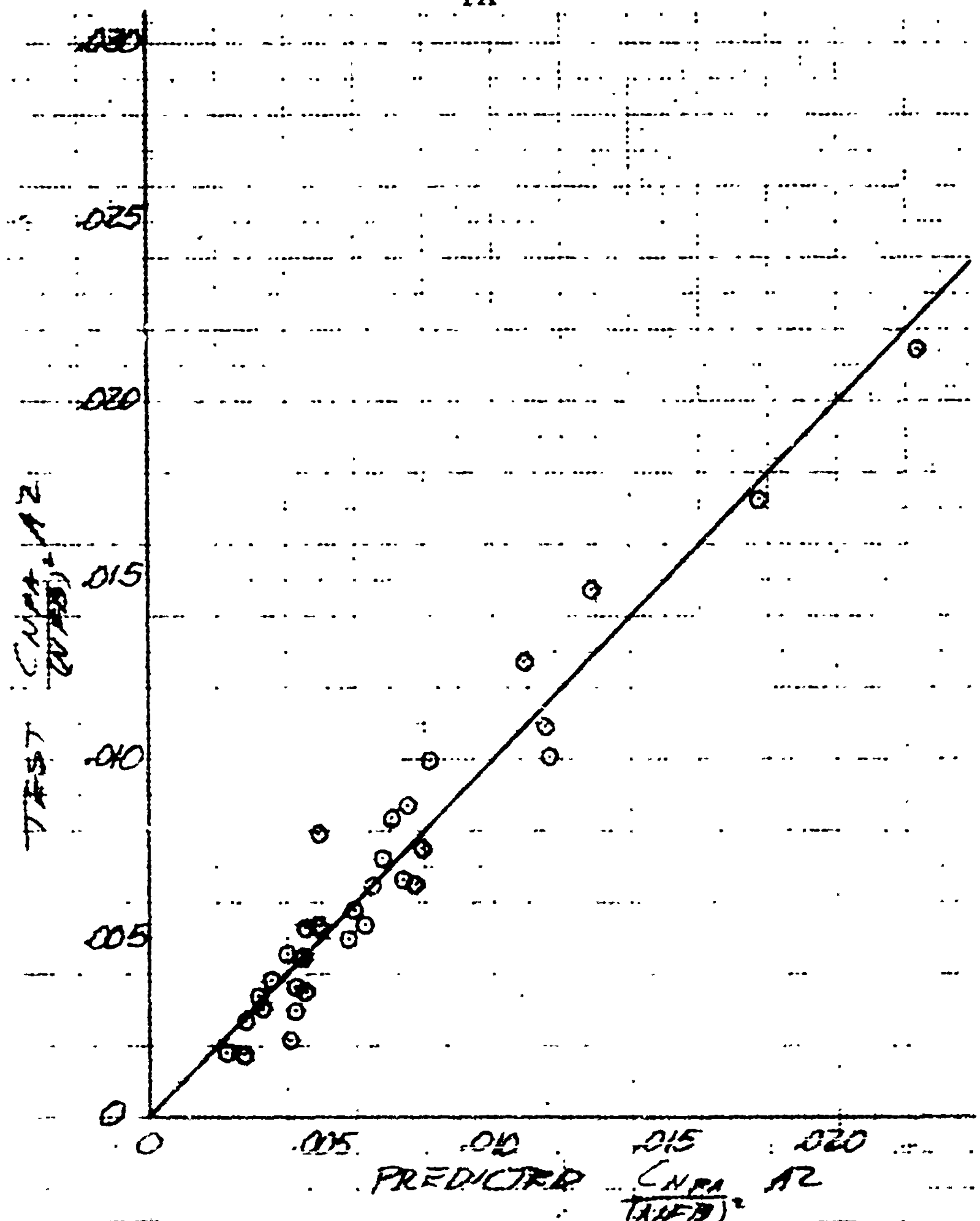


Figure 36 REGRESSION ANALYSIS AT $\alpha = 20^{\circ}$

$\alpha = 10^\circ$

$M = 0.6$

$$\frac{C_{N_{PA}}}{(NFB)^2} AR = .04891 + .0001625\ell - .0034690D$$
$$-.00002522C - .00015875\Delta X$$
$$+.000006405 \frac{PA}{FA} \times FSPD$$

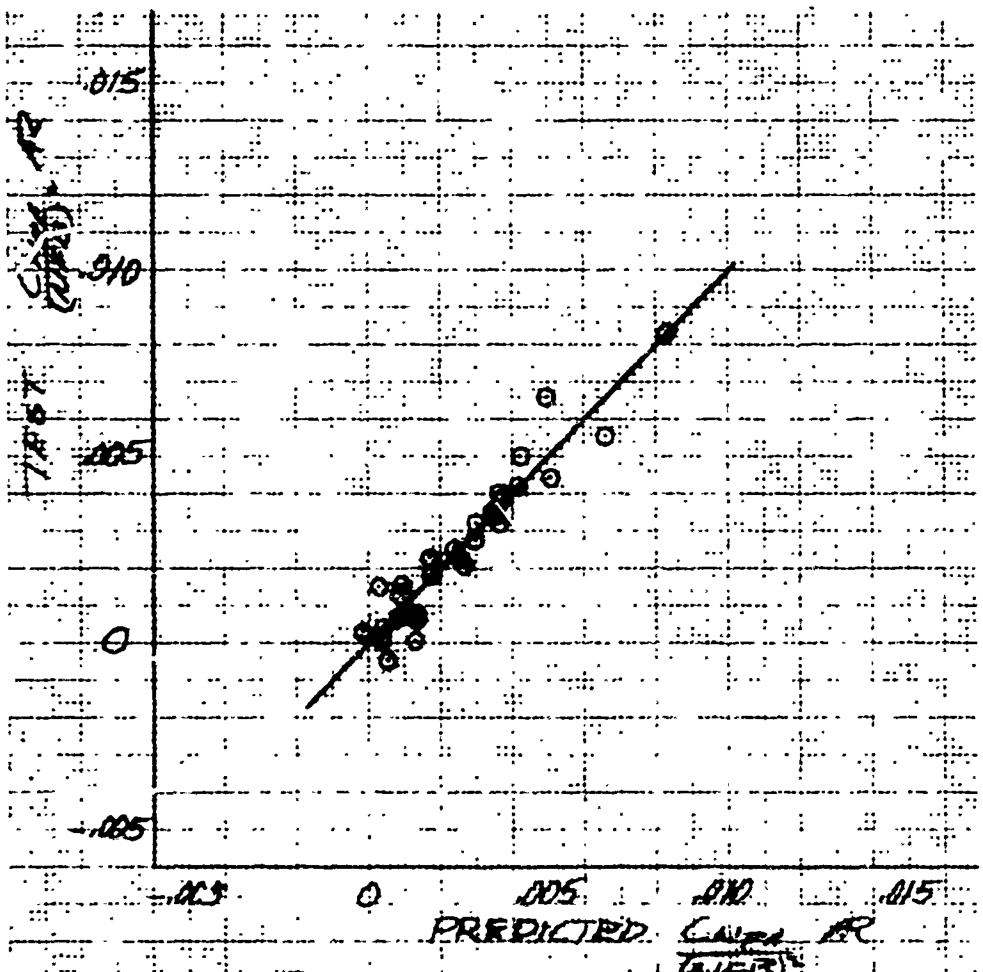


Figure 37 REGRESSION ANALYSIS AT $\alpha = 10^\circ$

$\alpha = 0.$

$M = 0.60$

$$\frac{C_{N_{PA}}}{(NFB)^2} AR = .07294 + .000221\,\ell - .004895D - .0008128C - .0001629\Delta X - .000003625\,\frac{PA}{FA} \times FSPD$$

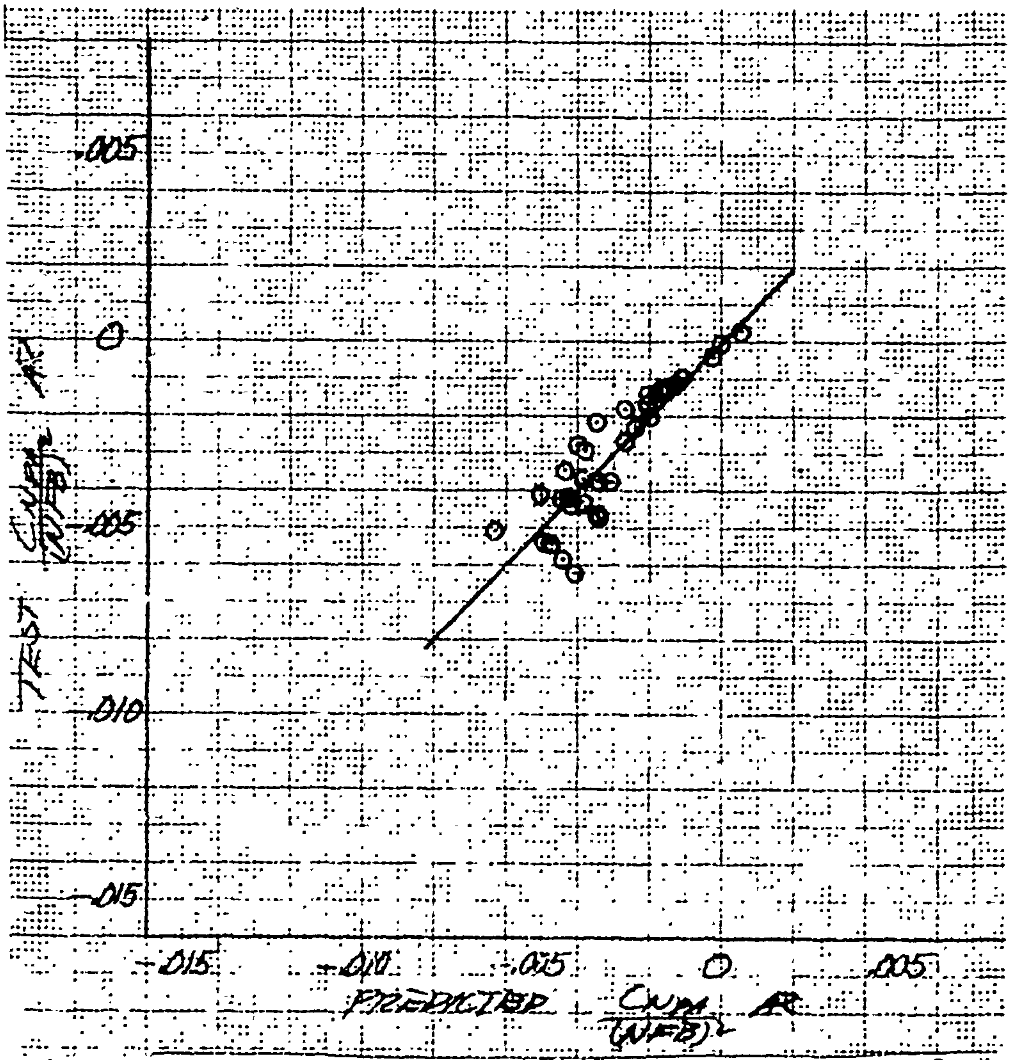


Figure 38 REGRESSION ANALYSIS AT $\alpha = 0^{\circ}$

$\alpha = -5^{o}$

M = 0.6

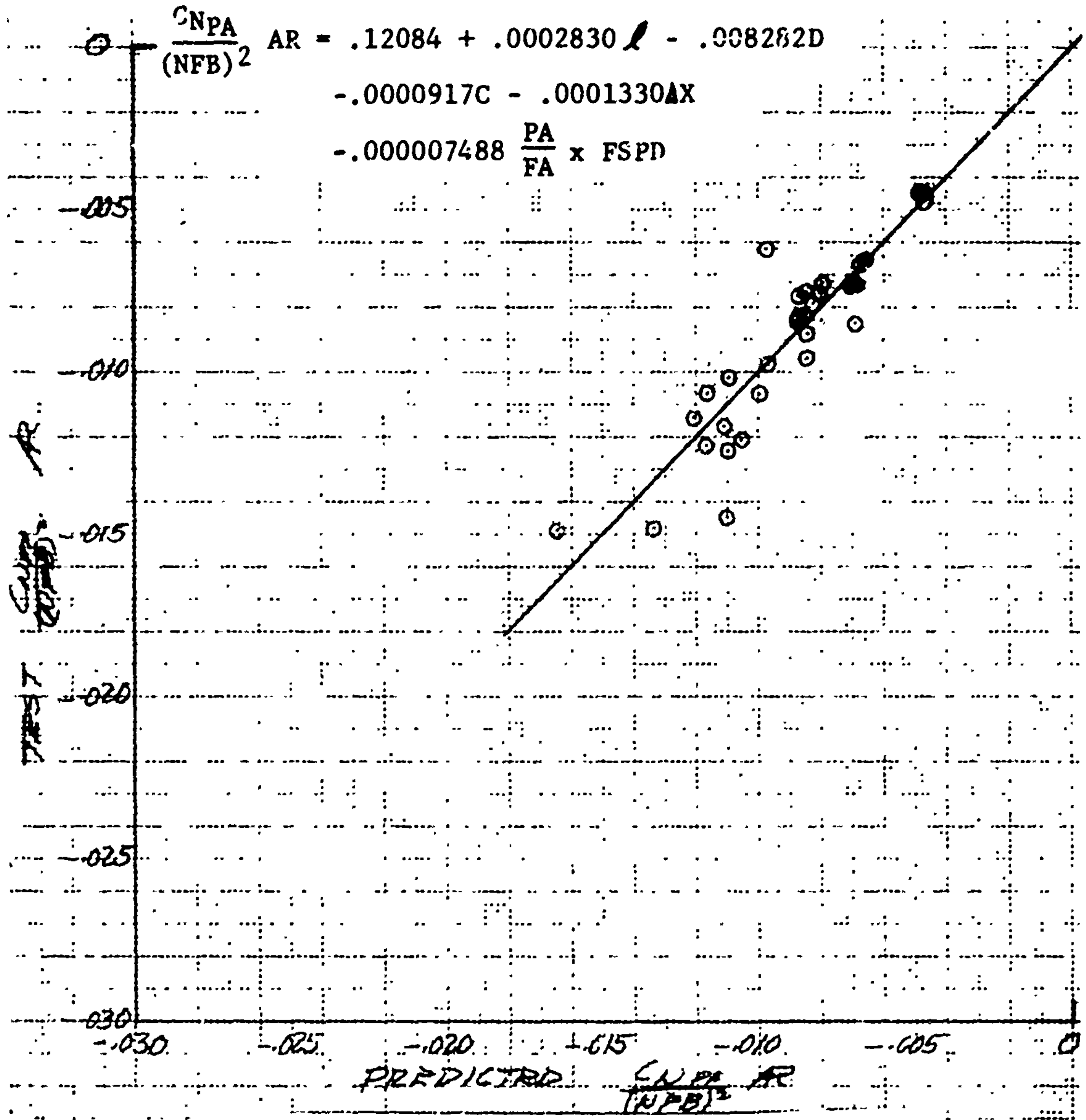


Figure 39 REGRESSION ANALYSIS AT $\alpha = -5^{o}$

$\alpha = 10^{\circ}$

M = 0.80

$$\frac{C_{N_{PA}}}{(NFB)^2} AR = .03591 + .0001492\ell - .002778D$$
$$-.000009558C - .0001563\Delta X$$
$$+.00000626 \frac{PA}{FA} \times FSPD + .000001\Lambda$$

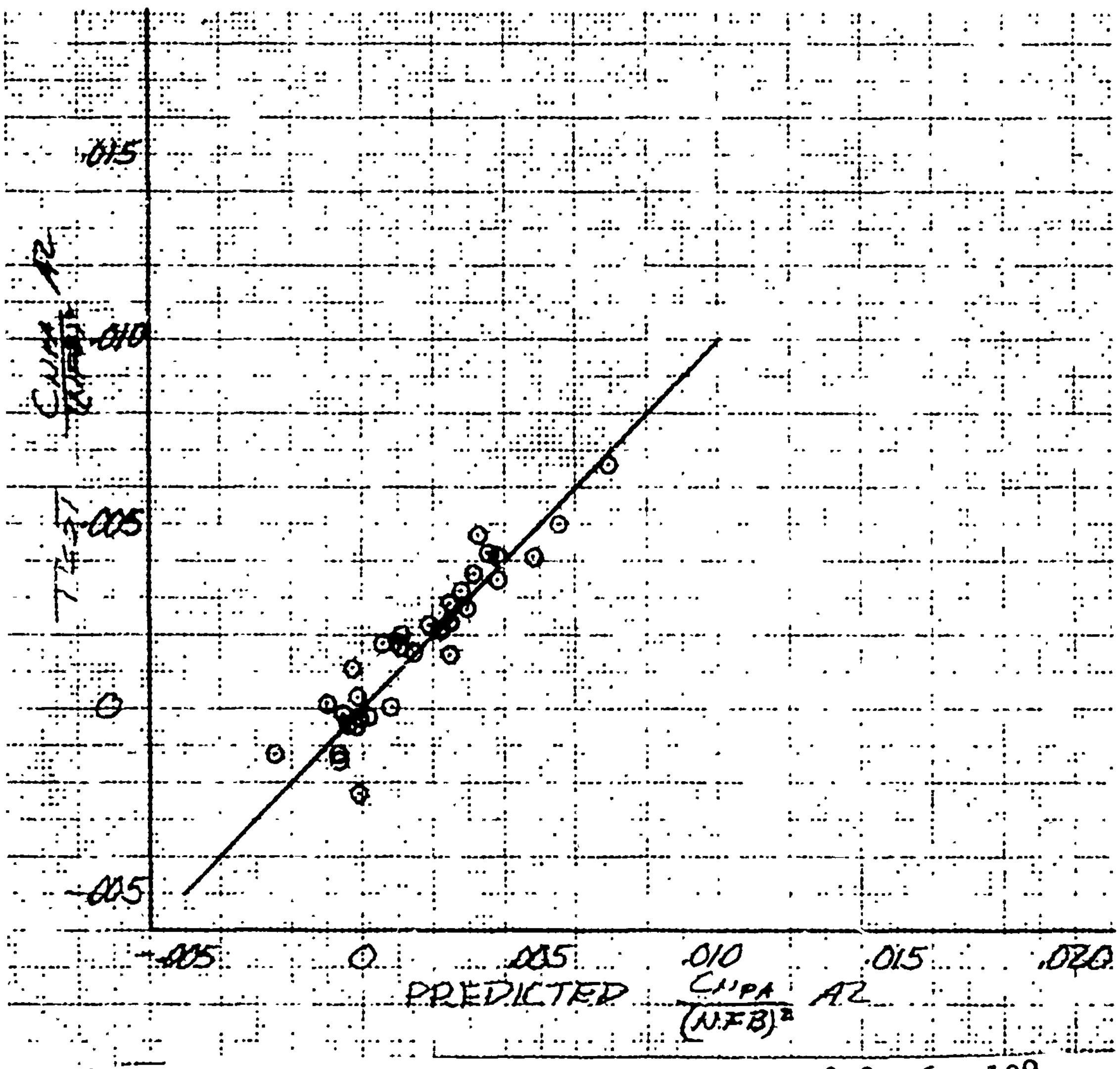


Figure 40 REGRESSION ANALYSIS AT M = 0 8, $\alpha = 10^{\circ}$

$\alpha = 20°$

M = 0.8

$$\frac{C_{N_{PA}}}{(NFB)^2} AR = .06121 + .0002365\,\ell - .003968D$$
$$-.0001365C - .0001964\,\Delta X$$
$$+.00000851\,\frac{PA}{FA} \times FSPD + .0001572\,\Lambda$$

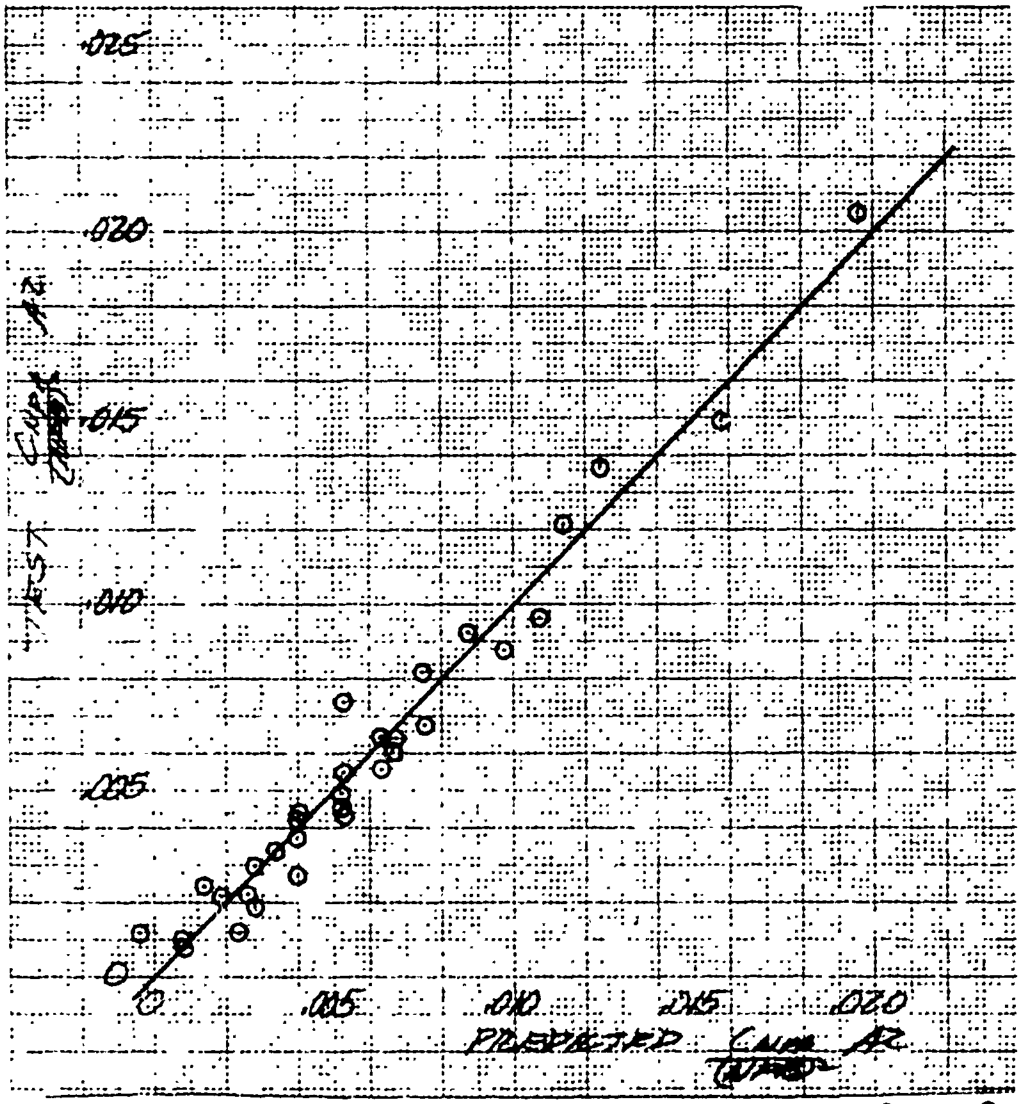


Figure 41 REGRESSION ANALYSIS AT M = 0.8, α = 20°

$$\alpha = 20^\circ$$

$$\Lambda_{LE} = 16^\circ - 72.5^\circ$$

$$M = .6 - .95$$

$$\frac{C_{N_{PA}}}{(NFB)^2} AR = .051604 + .000190\ell - .003519D$$
$$-.000039C - .000177\Delta X + .000013 \frac{PA}{FA} \times FSPD$$
$$+ .001895M - .004919M^2$$

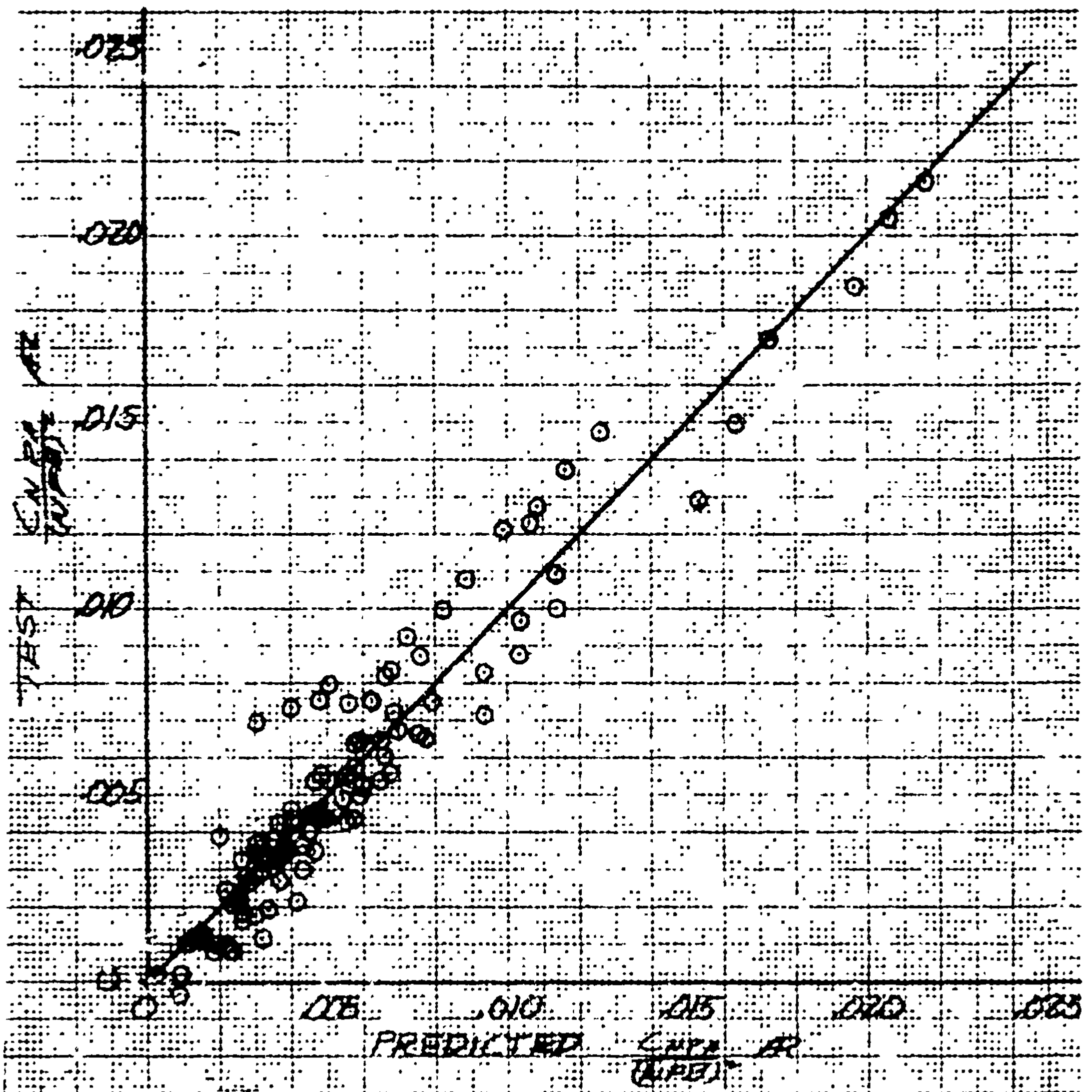


Figure 42 REGRESSION ANALYSIS INCLUDING EFFECTS OF SWEEP ANGLE AND MACH NUMBER

SECTION 4

MAJOR STORE GROUPINGS

As discussed in Subsection 3.2 it was decided that weighted regression analysis procedures would be used to analyze the entire mass of data from the F-111 wind tunnel program reported in Subsection 2.2. The conduct of this phase of the study is reported in the following subsections.

Analysis of the various configurations was conducted using the regression analysis program to establish geometric correlating parameters for each of the configurations under each of the major store groupings and subgroupings outlined in Subsection 3.2.2. In these investigations each component of force or moment was considered separately and correlations were done at particular store angles of attack of +16, +6, -4, and -9 degrees, and at sideslip angles of +10 and -10 degrees at 6 degrees angle of attack. The decision to conduct the correlation studies at separate angles of attack was made as a result of visual inspection of the data which demonstrated that variations in forces and moments with angle of attack were non-linear. This was very obvious at the high angles of attack where structural design conditions would occur.

During the initial planning for this program, it was felt that the forces and moments could be expressed as a function of a slope and an intercept of angle of attack and sideslip angle through the linear portion of the data. Nonlinearities occurred in the data at such low deflections, however, that studies devoted to this range would not have produced information useful to the design engineer concerned with practical structural design points. Conducting correlation studies at separate angles of attack and sideslip more than doubled the amount of work that was originally anticipated, however, it was felt that this was a necessary part of the study in order to produce a set of design charts which would be useful to the preliminary design engineer. The design charts are used for determination of aerodynamic loads and moments on external stores at design flight conditions from -5 degrees to +15 degrees angle of attack and for sideslip angles of +10 and -10 degrees at an angle of attack of 6 degrees.

With the guidelines above for data groupings, the regression analysis was then used to establish geometric correlating parameters for various geometry arrangements tested at subsonic and transonic Mach numbers during the F-111 wind tunnel testing. For convenience, because of its bulk, the data discussed in this section are located in an appendix (Appendix I). The particular weapons that were used for the various correlation studies are defined in Table II and data for the weapons-rack-pylon arrangements and the weapon-rack arrangements which were used to contribute to a particular correlation can be obtained by referring to Table III for the magnetic tape file number.

4.1 Weapons Cluster Plus Rack Plus Pylon

From the empirical studies and the weighted regression analysis that has already been accomplished it was anticipated that correlation could be achieved if the data were treated in a selective manner. This was accomplished by screening the various configurations to obtain geometric arrangements which had some aerodynamic similarity. This similarity was based on an empirical judgment obtained from a visual comparison of the aerodynamic forces and moments for various store arrangements. The first major store grouping chosen for analysis is a weapons cluster which can be either 3 weapons mounted on a triple ejector rack (TER) or up to six weapons mounted on a multiple ejector rack (MER). From the F-111 wind tunnel tests a substantial number of configurations with the TER rack were available for statistical analysis using the WRAP programs. Data for the MER rack configurations was very limited however, and it was not possible to utilize the WRAP program to establish geometric correlating parameters.

The weapons cluster configuration utilizing the TER rack were further divided into two subgroups containing data for (1) outboard stations and for (2) combinations of inboard stations.

4.1.1 Outboard Stations

During the initial attempts to arrive at geometric correlating parameters for the weapons clusters at the outboard stations it was observed that data for both the MER and TER rack configurations could not be combined in the same statistical analysis. It was decided that the initial studies would only consider the TER weapon arrangements

because the amount of data available was much more extensive than for the MER rack. The results of the weighted regression analysis for these TER arrangements are shown on pages 99 through 218 of Appendix I. The equations produced by the mathematical regression program was a linear equation containing the various geometric correlating parameters multiplied by a constant value. The fact that the correlating equation is linear makes it convenient to add correctors for such additional effects as the difference between MER and TER racks or for additional effects that the engineer may be able to define from other data sources.

4.1.2 Inboard Stations

Results of weighted regression analysis for these TER rack store arrangements are contained on pages 129 through 158 of Appendix I. In order to obtain sufficient data points for input into the regression analysis program it was necessary to load data for all of the various inboard pylon stations in the same study.

4.2 Weapons Cluster Plus Rack

As stated previously, configurations for which data was taken on the left wing were duplicated on the right wing without the pylon loads. Data for these statistical correction studies are shown on pages 159 through 218 of Appendix I for the TER rack configuration.

4.2.1 Outboard Station

The results of the correlations studies using the regression program are shown on pages 159 through 188 of Appendix I.

4.2.2 Inboard Station

The results of correlations for inboard stations with TER racks are shown on pages 189 through 218 of Appendix I. As was the case with studies conducted for inboard stations reported in Subsection 4.2.2 it was necessary to group all data for various inboard pylon locations into the same study.

4.3 Multiple Ejector Rack (MER) Analysis

The multiple ejector rack (MER) was able to carry up to six weapons mounted in two rows of three weapons each. During the F-111 wind tunnel testing this rack most often carried M-117 bombs. The amount of data obtained with the MER rack and weapons however was not sufficient to allow use of the mathematical statistical techniques which were utilized for correlation of the TER rack. Because of this it was necessary to employ other techniques to obtain prediction methods applicable to the MER rack configuration.

From an analysis of the limited MER rack data it was found that modifications could be made to the TER rack correlating equations which would make these same equations satisfactory for prediction of aerodynamic loads acting on the particular MER rack configurations. These modifications to the TER rack prediction equations were accomplished by following a set procedure described below.

A particular force or moment coefficient for the MER rack was first predicted using an appropriate TER rack equation. This predicted value was then compared to the actual MER rack wind tunnel test data. From an empirical analysis it was found that by adding a multiplying factor to the left side in the equation, (Number of Bomb)^2/(Number of Front Bombs)^2, the predicted value would closely agree with the test value. A final correction in the form of a constant was then added to the right side of the predicting equation to make the predicted value and test value agree.

An example of the method of defining the constant for the normal force for a MER rack configuration is shown in Figure 43 for each angle of attack for which TER rack prediction equations were developed.

Using the same correction format for the other four coefficients of force and moments, the constant to correct the modified TER rack equations to the exact experimental value was defined and the values are tabulated in the table of coefficients in Appendix II.

6-M - 117 WEAPONS + MER RACK DIMENSIONS, $\Lambda = 26^{\circ}$

$l = 185.8$ in.
$D = 16.5$ in
$C = 123.0$ in
$\Delta X = 58.0$ in

$\frac{PA}{FA} \times FSPD = 377.0$ in

(1) Calculate $C_{N_{PA}} \times \frac{AR}{NFB^2}$, Appendix I

(2) Correct value (1) above by $\frac{NB^2}{NFB^2}$

(3) Obtain Constant C_{MER} @ α const

@ $\alpha = 16^{\circ}$, $C_{MER} = -.00075$
" " $= 6^{\circ}$, " $= -.0013$
" " $= -9^{\circ}$, " $= +.0030$

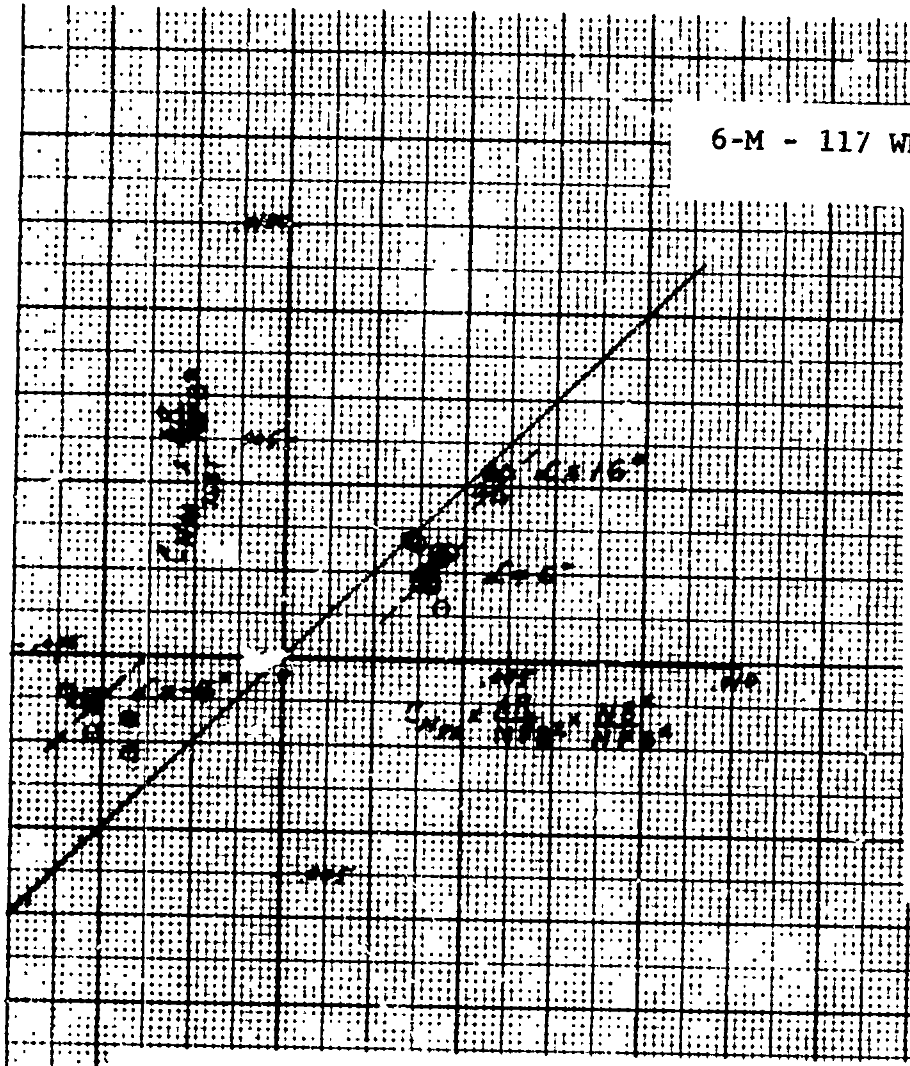


Figure 43 DETERMINATION OF MER RACK CORRECTIONS

4.4 Single Weapon Plus Rack Plus Pylon

For store configurations considered in this grouping a single weapon was considered to be a store mounted directly to a pylon. The results of these studies are illustrated on pages 219 through 249 of Appendix I.

4.4.1 Outboard Station

The results of the regression analysis study for this classification of stores are contained on pages 219 through 249.

4.4.2 Inboard Station

There was insufficient F-111 model wind tunnel test data to accomplish a weighted regression analysis study of configurations in this category.

4.5 Single Weapon Plus Rack

As was explained in Section 4.2 for arrangements classified as "clustered weapons", strain gage data taken on the left wing with weapon rack and pylon was duplicated without the pylon loads being measured on the right wing. Statistical correlations of data for single weapons plus rack, inboard and outboard stations, are illustrated on pages 249 through 278.

4.5.1 Outboard Station

The results of weighted regression analysis studies for single weapons on outboard stations are shown on pages 249 through 278.

4.5.2 Inboard Station

As was the case with the inboard pylon station for single weapon plus rack plus pylon, there was an insufficient number of configurations which could be used for data points for a meaningful statistical study

SECTION 5

EFFECTS AT SUPERSONIC SPEEDS

Aerodynamic force and moment coefficient equations for the subsonic and transonic speeds were developed from the results of statistical methods of data correlation. Statistical methods, however, require a large volume of data for adequate sampling and curve fitting. From the F-111 wind tunnel testing only a few of the total number of configurations were tested at supersonic speeds. This precluded the use of mathematical techniques of statistical analysis to establish correlation as a function of various geometry parameters.

In order that corrections could be provided for the aerodynamics engineer to calculate external store loads at supersonic speed, it was necessary to take a different approach than that used to determine loads at subsonic and transonic speeds.

As shown in Section 4.3 the statistical methods utilized in this program produced linearized equations which could be corrected or modified. In Figures 44 through 49, a store load correction as a function of supersonic Mach number is shown for various configurations tested on the F-111 model. The corrections are developed at a constant angle-of-attack of the store. This factor can then be applied directly to the subsonic values developed from the statistical equations for appropriate configurations.

The data presented in this section are for particular F-111 configurations which have also contributed to the data used in the previous analysis in Section 4.3 for the single weapons. It would, therefore, be quite easy to identify a base configuration to which the corrections could be applied. The data will, of course, be limited in application to single stores until additional testing is obtained to identify the more important geometry parameters associated with clustered stores.

If data is obtained from other sources it would be necessary to make comparisons at subsonic speeds between the new data source and the F-111 results in order to establish some similarity of configurations. Although there is obviously an insufficient amount of data to develop a generalized data source from the available F-111 results at supersonic speeds, the F-111 data presented in Figures 44-49 can be used to provide compressibility

correction trends to the new data. In Appendix II, the data in these figures are replotted as a function of angle-of-attack for easier design application.

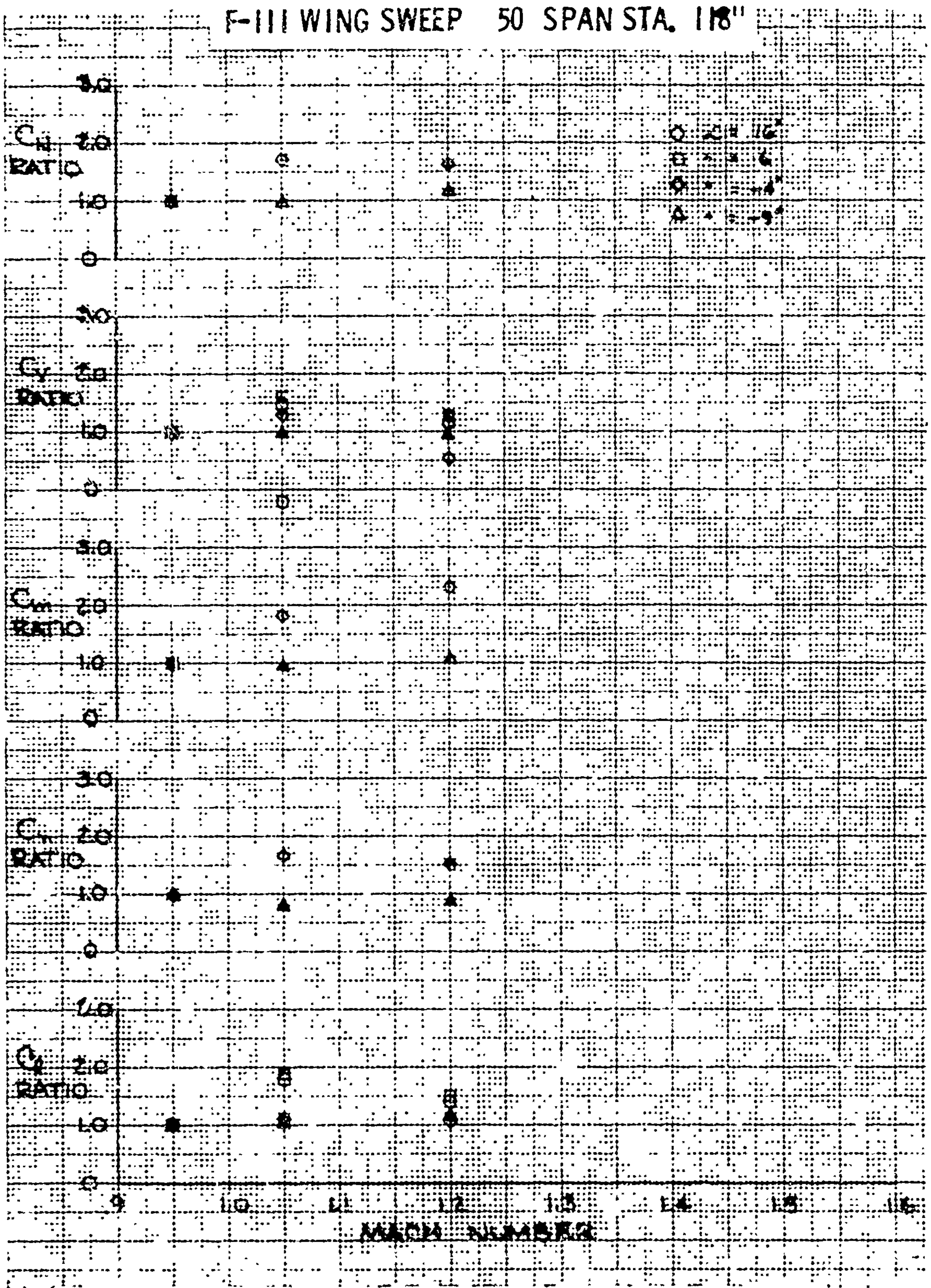


Figure 44 SUPERSONIC DATA FOR M-117R, AFT CLUSTER

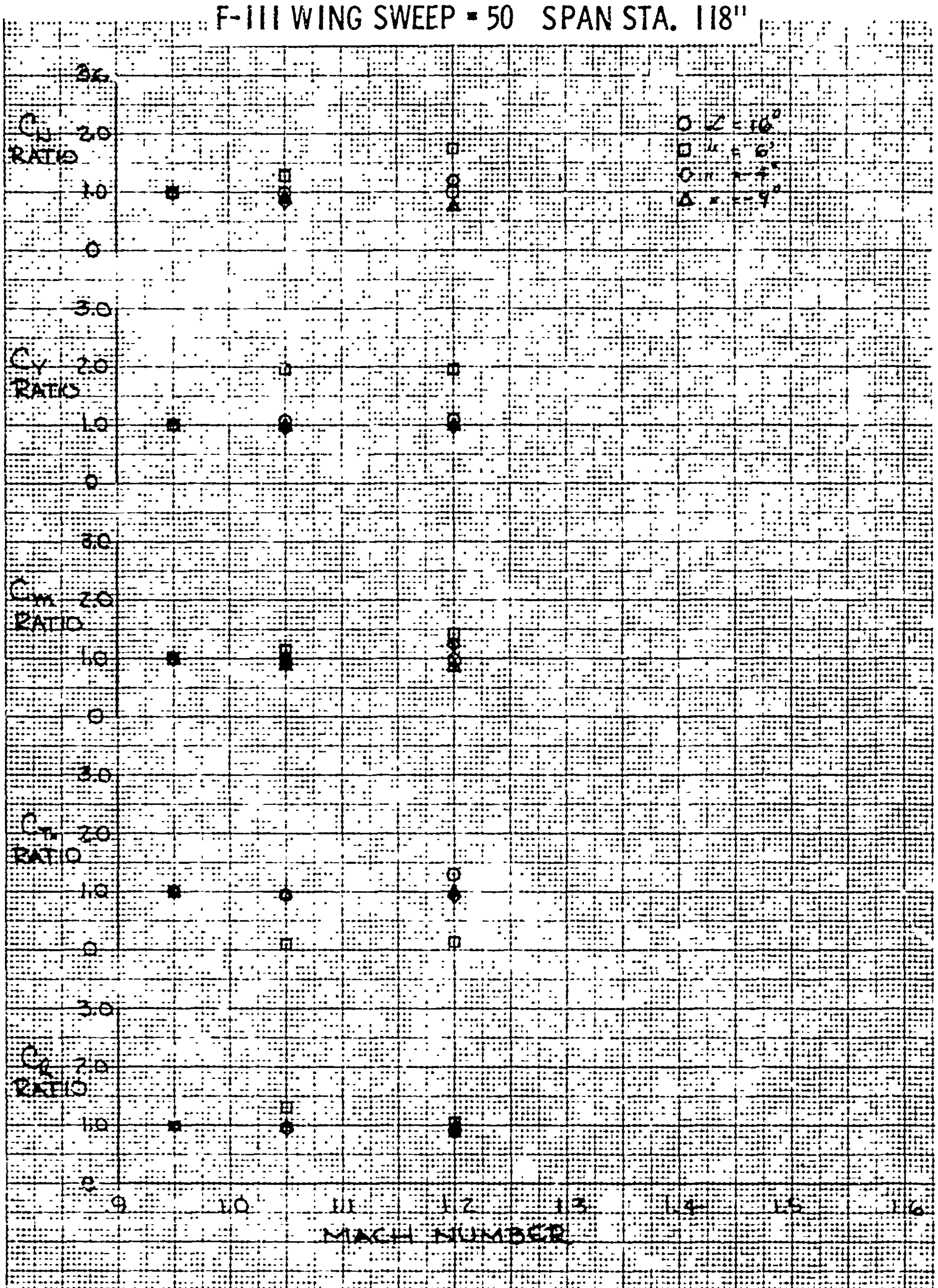


Figure 45 SUPERSONIC DATA FOR M-117R, FORWARD CLUSTER

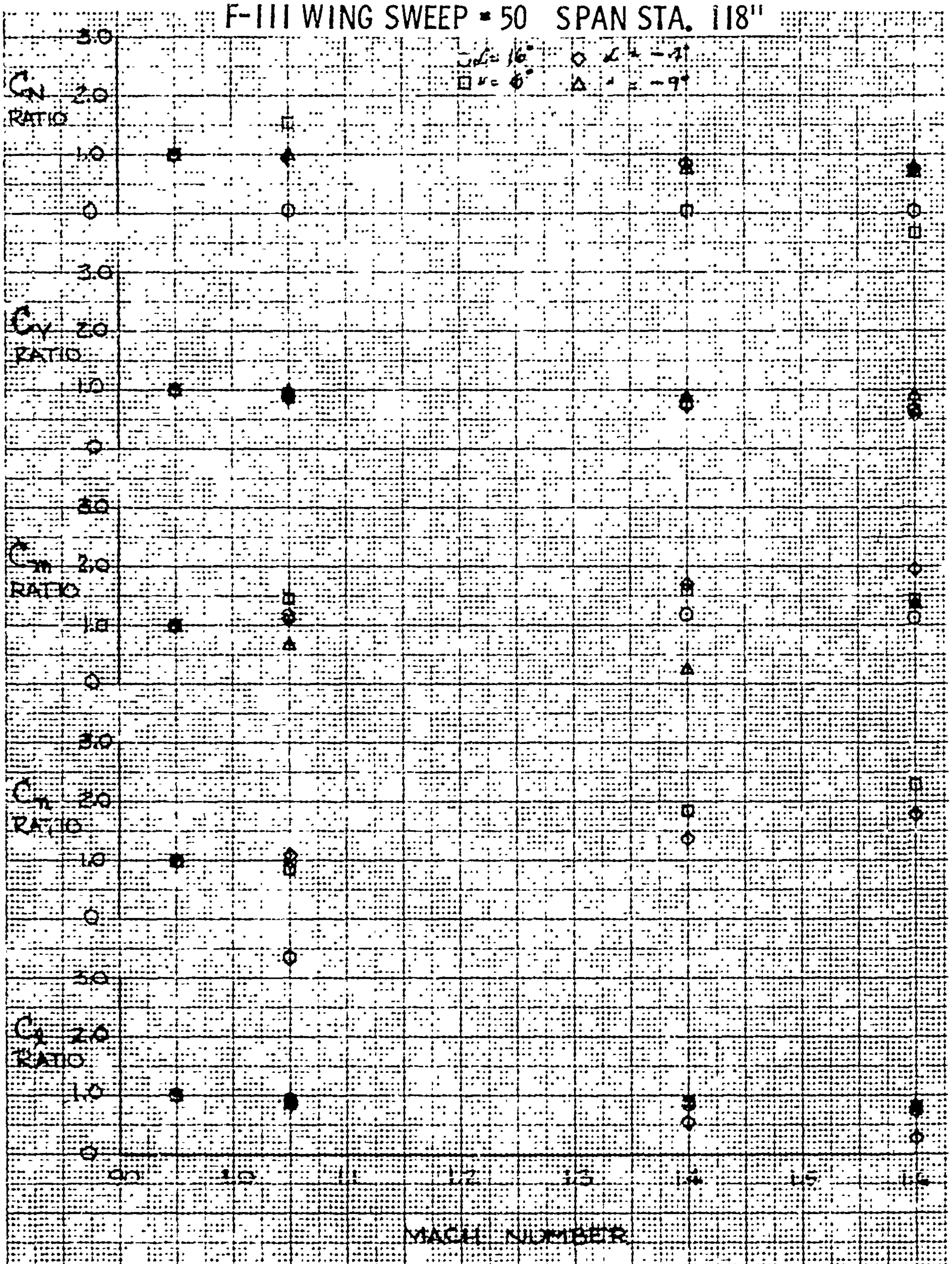


Figure 46 SUPERSONIC DATA FOR B-43

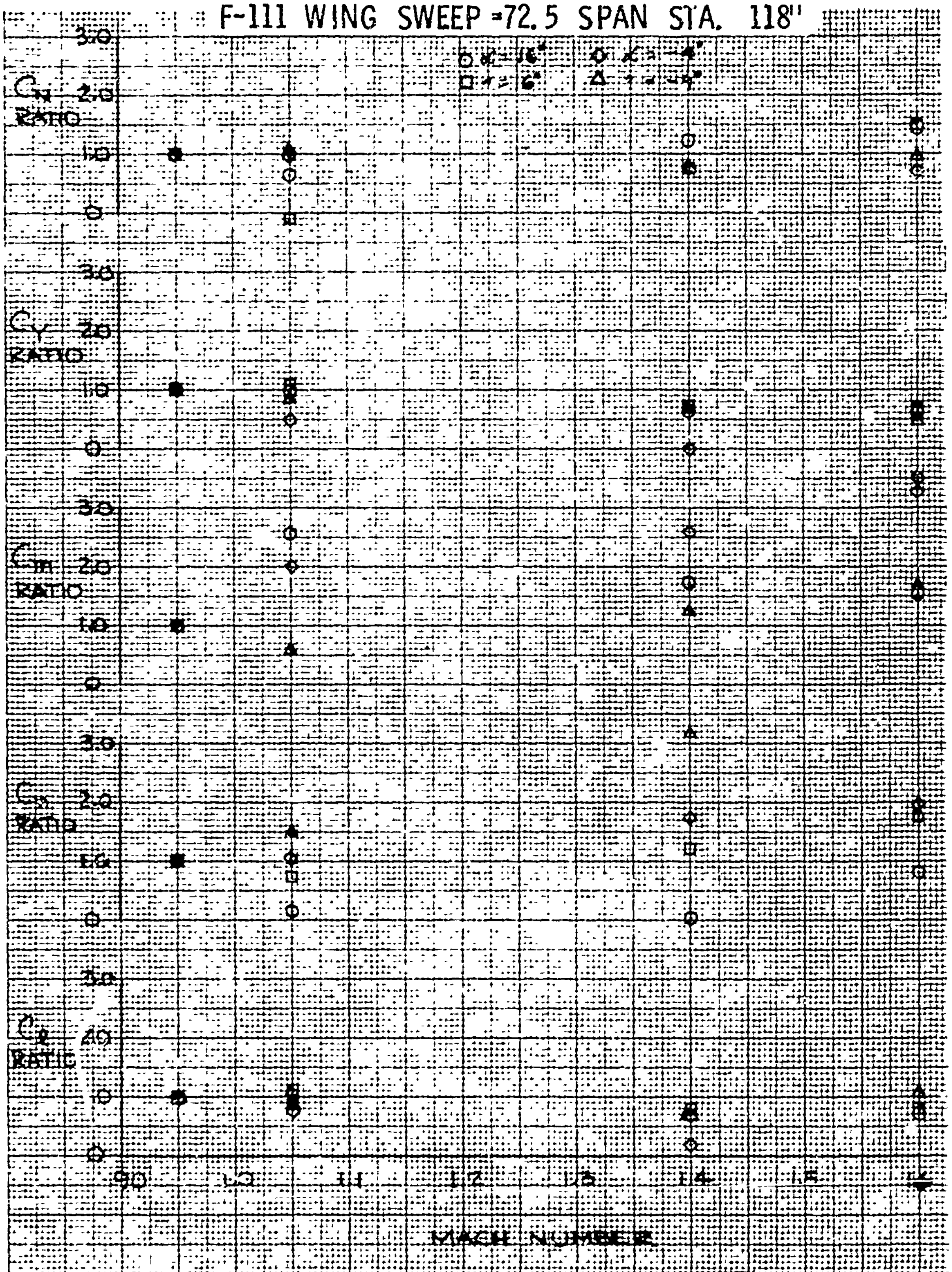


Figure 47 SUPERSONIC DATA FOR B-43

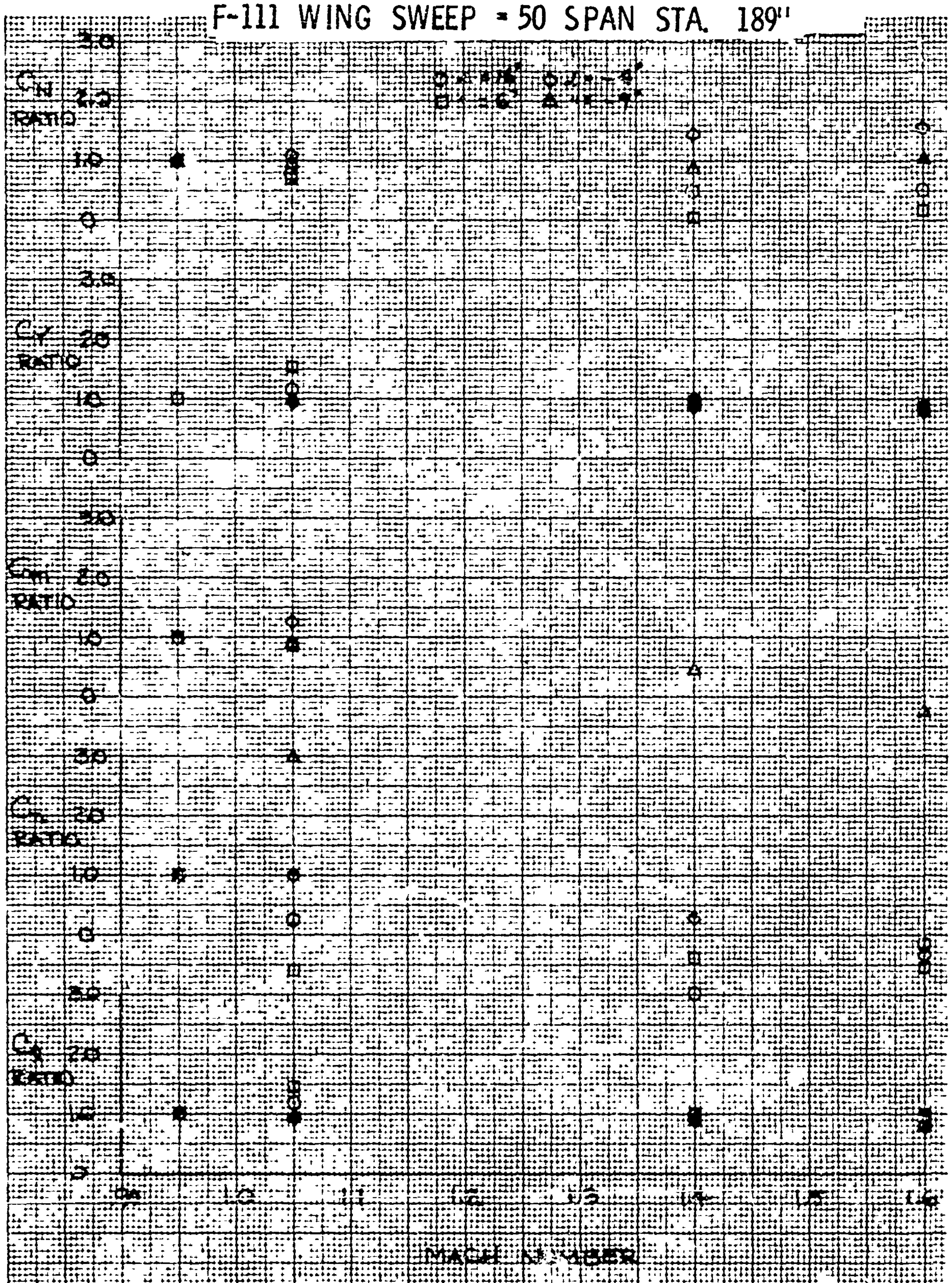


Figure 48 SUPERSONIC DATA FOR B-43

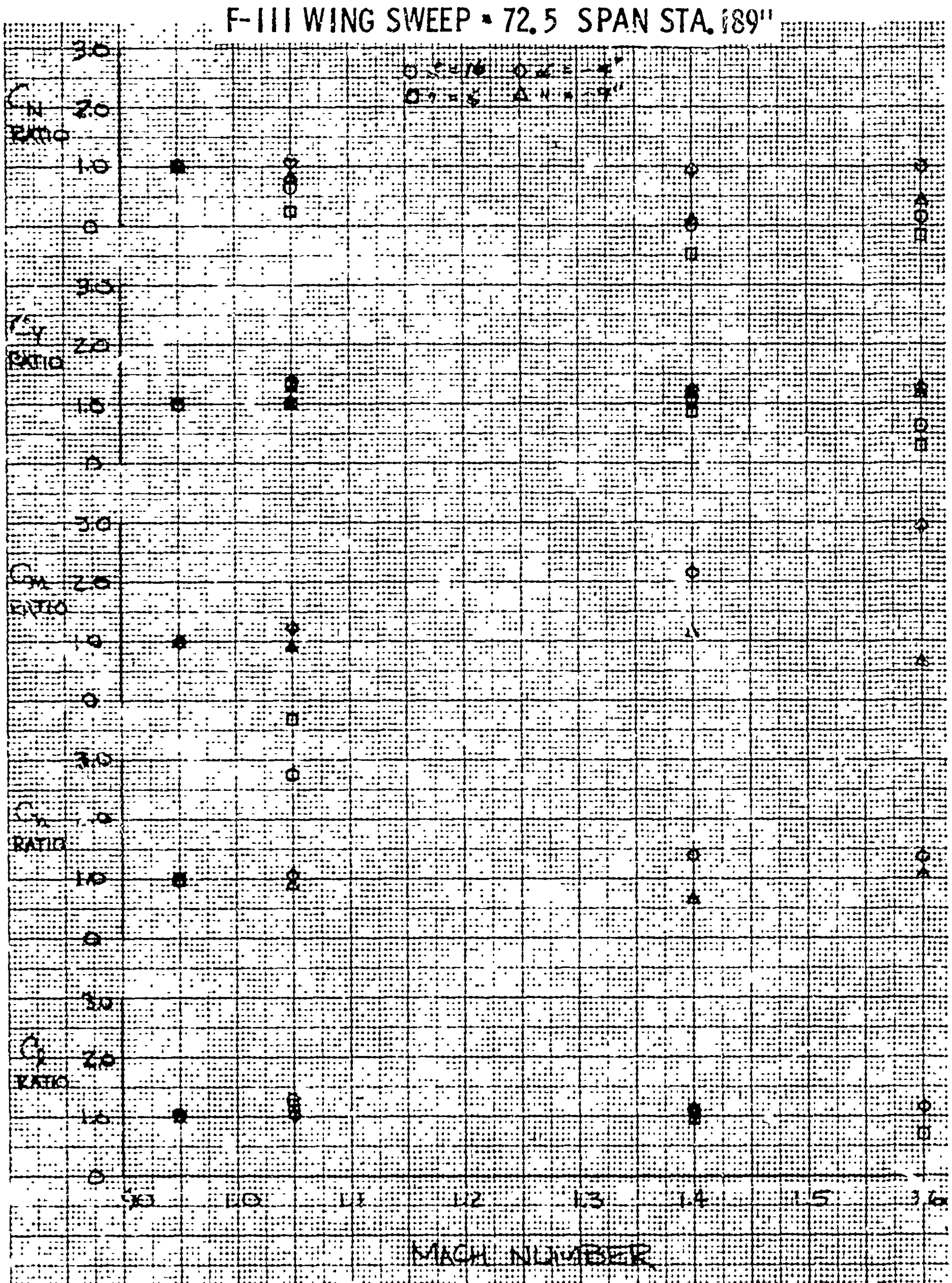


Figure 49 SUPERSONIC DATA FOR B-43

SECTION 6

DATA FROM OTHER SOURCES

During the study period, a continuous survey of experimental data from other sources was maintained. There is, of course, an enormous amount of data where forces and moments were obtained on various types of store configurations in the presence of differing wing-body geometries. In general, however, the bulk of the testing involved a single store on a single pylon, and the objective of the testing was to establish the variation in the aerodynamic forces and moments acting on this single store as its position was changed and as the Mach number was varied. A list of these sources is contained in References 14 through 25.

The major objective of the present study was to establish a method of predicting aerodynamic loads on generalized external store arrangements from an empirical correlation of experimental data. From the F-111 data, arrangements of up to eight wing pylon stations with as many as six stores on a pylon were evaluated. The single-store configuration must then be considered to be a special case when considered in the context of all of the configurations examined in the present study.

One significant contribution which could be obtained from data extraneous to the F-111 wind tunnel data would be the determination of other geometry parameters which would significantly influence external-store aerodynamic loads but which were not evaluated in the F-111 testing. An example of such a geometric parameter is the vertical distance from the store to the bottom of the wing surface. This was not a variable geometry parameter on the F-111 because the pylon length was dictated by constraints due to flap deflection and adequate ground clearance.

In Figure 50 data are shown from Reference 16. From this reference it can be seen that the vertical displacement of the store makes a substantial difference to the magnitude of the normal force acting on the store but in this particular test does not materially affect the other store forces or moments which were measured. It would not be proper to assume that the results of these tests are universally true for all configurations. It may be possible, however, to draw generalized conclusions from such tests which would be

of value in establishing trends for other configurations. The data from this reference could be applied to the predicted values from Section 4.4 for similar geometric arrangements. This would be accomplished by multiplying the predicted value of a particular force or moment by the ratio of the force or moment from Reference 16 at the new vertical location to the value at the vertical location equal to the F-111 data of Section 4.4.

Data from the list of references could be utilized to expand the geometric variations beyond the values tested during the F-111 program. As was previously mentioned, however, most of the data contained in these references are for single-store arrangements. Theoretical aerodynamic procedures such as those contained in References 26, 27 and 28 have recently been developec which are able to analyze very complex geometric arrangements. Some of these programs will actually analyze aircraft configurations with some representation of single external store installations. The aerodynamicist must therefore make a choice of expanding the empirical techniques developed in this report or of utilizing a correlation of experimental and theoretical aerodynamic results to arrive at predictions for new aerodynamic configurations. For more complex external store arrangements with several wing positions occupied, theoretical techniques for aerodynamic analysis are much further away and development of empirical prediction techniques based on correlations of experimental data will be useful for many years to come.

From Reference 16 (p. 81)

M = 0.95, Single Store + Pylon

□ - z/d = 0.5 ◇ - z/d = 1.0

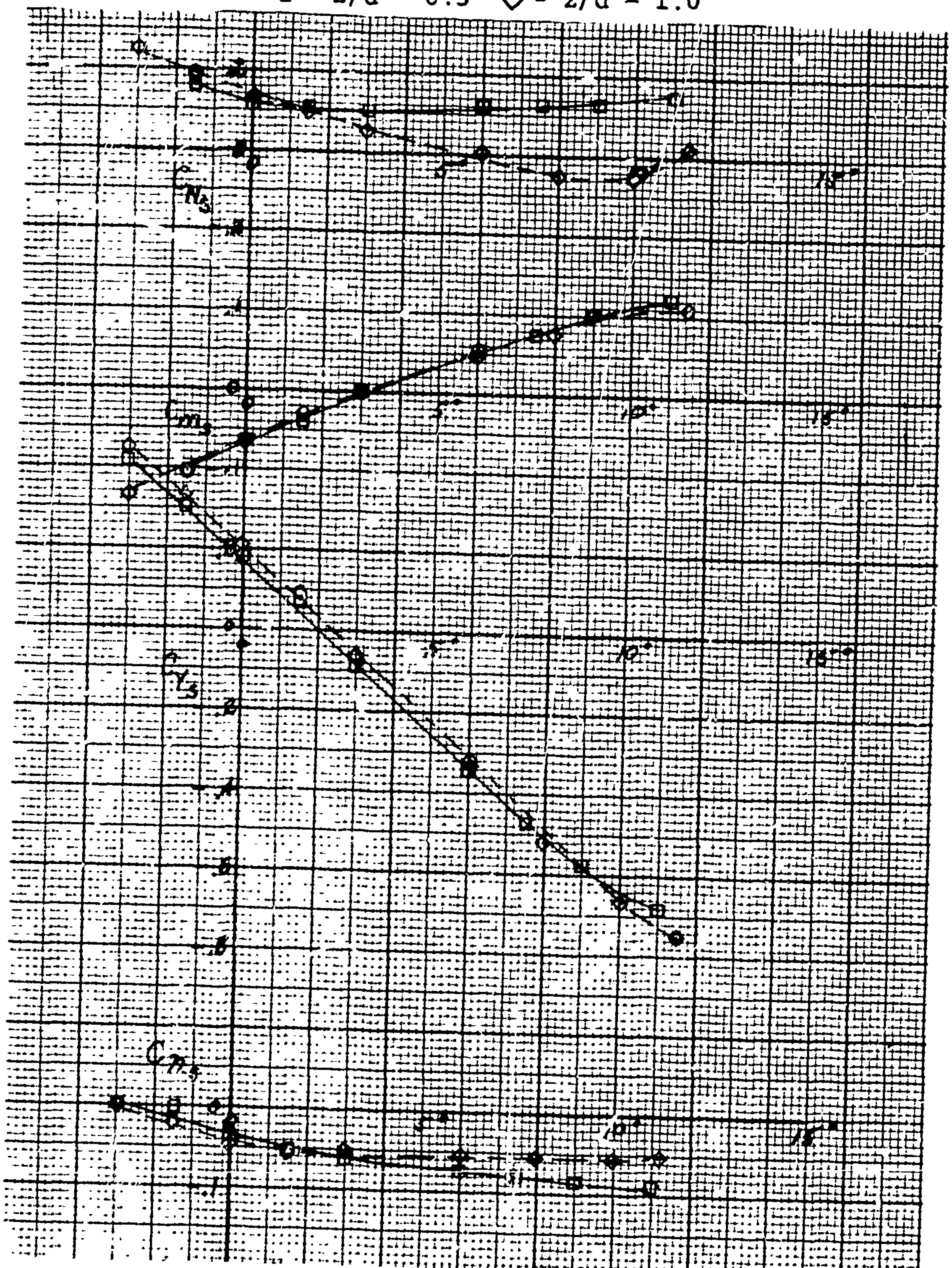


Figure 50 EFFECT OF STORE VERTICAL LOCATION

SECTION 7

PREDICTION OF AERODYNAMIC FORCES AND MOMENTS ACTING ON EXTERNAL STORES

The mathematical regression analysis techniques used in this study produced a series of linear equations containing the pertinent geometric correlating parameters. A linear equation was produced for each of five forces or moments acting on a particular store grouping at various angles-of-attack and side slip.

In Appendix I, a comparison is shown of the predicted valve of a particular force or moment versus the corresponding experimental value obtained for the F-111 wind tunnel test data. The linear correlating equation used for each comparison is shown at the top of each plot. Two concepts for the solution of the aerodynamic coefficients are provided.

A graphical solution of the coefficient equations is shown (two-thirds size) in Figure 51. The stepwise procedure for using the graphical design chart is found on page 93. These charts, in full size, are available from the Air Force Flight Dynamics Laboratory/FBE, Wright-Patterson A.F.B. Ohio 45433. Because of their volume (179 charts), loss of accuracy when reduced in size, and time consuming application, the design charts were not incorporated in this report.

A direct analytical solution is shown on p. 94. This concept, as opposed to the graphical solution, takes advantage of the speed, accuracy and wide availability of small calculators. In Appendix II, the aerodynamic coefficient equations and the equation coefficients (empirical constants) are conveniently arranged for direct computation. The empirical constants are tabularized, easily selected and keyed to the aerodynamic coefficient equations. The two example problems on page 94 show the predicted normal force coefficient acting on two different types of store configurations. In the first example, a prediction is made for three weapons mounted on a MER rack at the outboard location with two inboard pylon locations occupied. This prediction can be compared with that shown in the design chart on page 92. In the second example a prediction is made for six weapons mounted on a MER rack adjacent to the fuselage.

Appendix II is intended to be used as a preliminary design handbook for the determination of aerodynamic loads acting on external stores. It is self-contained so that it may be removed and used more conveniently

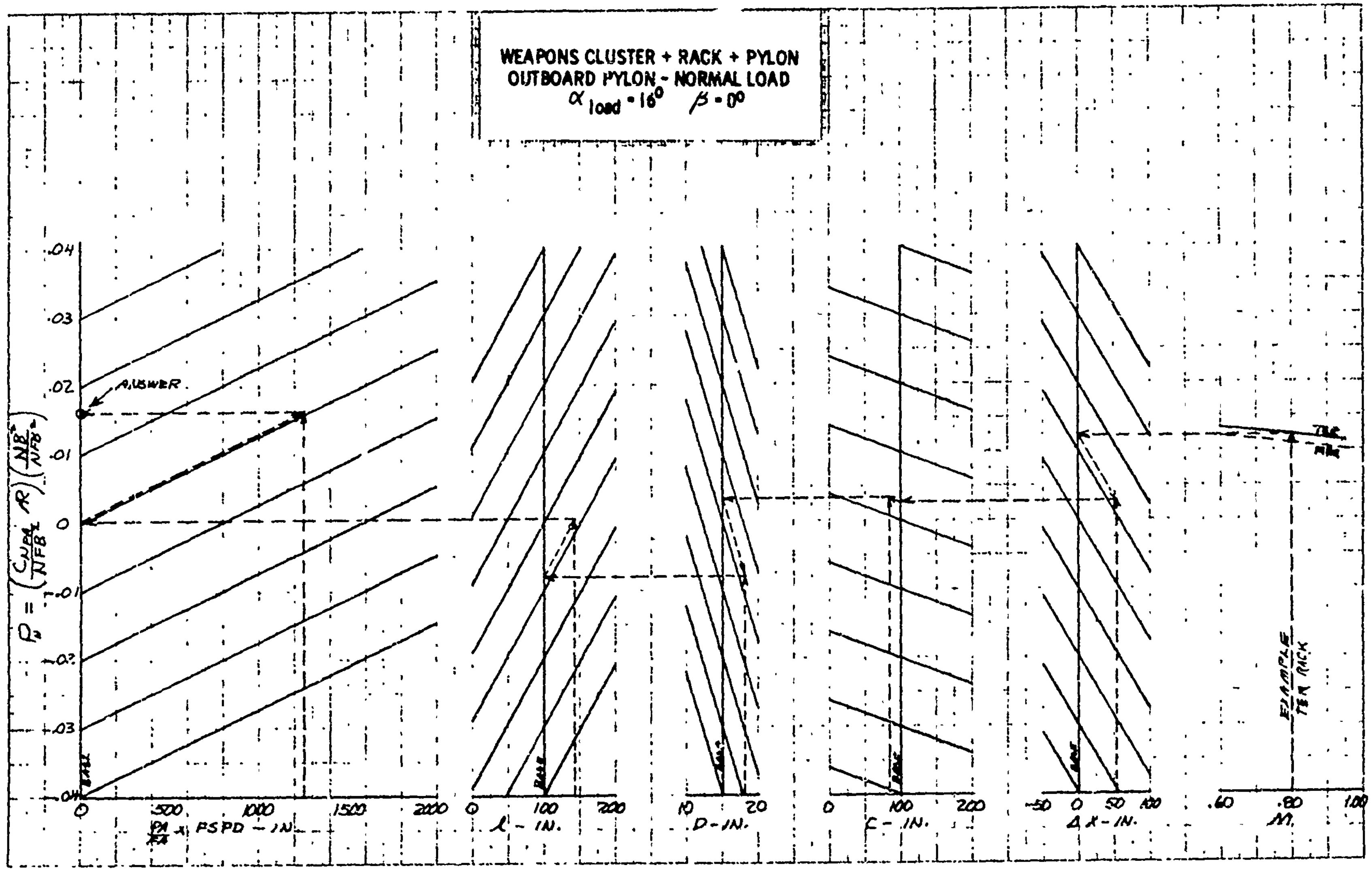


Figure 51 EXAMPLE OF DESIGN CHART

USE OF EXTERNAL STORE LOADS
HANDBOOK CHARTS

1. Enter Mach number (point 1) and project upward to curve (2).

2. Move horizontally to the "ΔX" base line (3). Follow the parallel guidelines until the desired "ΔX" value (4) is reached (5).

3. Move horizontally to the "C" baseline (6). Follow the parallel guidelines until the desired "C" value (7) is reached (8).

4. Move horizontally to the "D" baseline (9). Follow the parallel guidelines until the desired "D" value (10) is reached (11).

5. Move horizontally to the "λ" baseline (12). Follow the parallel guidelines until the desired "λ" value (13) is reached (14).

6. Move horizontally to the "$\frac{PA}{FA}$ x FSPD" baseline (15). Follow the parallel guidelines until the desired "$\frac{PA}{FA}$ x FSPD" (16) is reached (17).

7. Move horizontally to the left and read P_N (18).

8. P_N for TER loads is read at point 18.

NOTE: Use the proper curve marked TER for the triple ejector rack or the curve marked MER for the multiple ejector rack. When only one curve is present values for the TER rack only may be obtained.

EXAMPLE PROBLEM

$\alpha = 16^{\circ}$ $\beta = 0^{\circ}$
MN = 0.80

Normal Load Coefficient
Outboard Station

Configuration

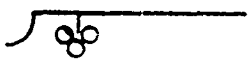
BLU-1CB Weapon
TER Rack + Pylon

l = 143.5 in
D = 18.2 in
C = 84.0 in
Δx = 53.0 in
$\frac{PA}{FA}$xFSPD = 1250.6

$$\frac{C_{N_{PA}}}{NFB^2}(AR) = .052312 + .00019\,l - .003519D - .000039C$$
$$-.000177\Delta x + .0000126\frac{PA}{FA}(FSPD) - .00369M^2$$
$$= .052312 + .02725 - .064 - .003275$$
$$-.00938 + .01575 - .00236$$

Note: $C_{MER} = 0$ for TER

$$= .01647 \text{ (check chart page 92)}$$



M-117 Weapons
MER Rack + Pylon

l = 185.8 in
D = 16.5 in
C = 123.0
Δx = 58.0
AR = .2423
$\frac{PA}{FA}$xFSPD = 377.0

$$\frac{C_{N_{PA}}}{NFB^2}(AR)\left(\frac{NB^2}{NFB^2}\right) = .052312 + .00019\,l - .003519D - .000039C$$
$$-.000177\Delta x + .0000126\frac{PA}{FA}(FSPD) - .00369M^2$$
$$-.001$$

$$\frac{C_{N_{PA}}}{NFB^2}(AR)\,\frac{36}{9} = .052312 + .0353 - .05806 - .00479 - .01028$$
$$+.00475 - .00236 - .0010$$
$$= .016872 - .0010$$
$$= .015872$$

$$\frac{C_{N_{PA}}}{NFB^2}(AR) = \frac{1}{4}(.015872) = .00397$$

SECTION 8

APPLICATION AND LIMITATION OF DATA

The studies reported in this document were designed to synthesize the large mass of F-111 external store loads wind tunnel results into a format which would be useful to the preliminary design engineer. This program produced a catalogue of major classifications of external stores and established mathematical relationships which could be used to determine five components of force and moment coefficients acting on the store configuration.

The mathematical relationships consisted of linearized equations containing geometric parameters developed from the empirical correlations of the F-111 wind tunnel results. Because the prediction equations were developed from a specific set of wind tunnel results directly dependent on the F-111 model geometry it is important for the engineer to have some appreciation for the limitations of the geometric variables which were incorporated in the correlation studies. Since the only guide to the limitations that the engineer might recognize are the actual geometries used in the correlations it might be sufficient to refer the engineer back to Figures 1 through 17 and Figures 20 through 25. In order to provide a more concise reference for geometry limitations, however, a schematic diagram of what are felt to be limiting geometry parameters pertinent to this study are shown in Figure 52.

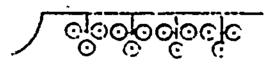
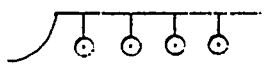
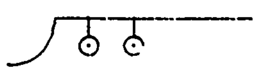
Weapon Cluster	Wing $Sweep_{LE}$	Weapon Limitation Dia.	Weapon Limitation Length	Rack Configuration (No. Bombs)
 1 to 4 stations	16° - 30°	18″	180″	MER -(6) TER -(3)
 1 or 2 stations	16° - 72.5°	18″	180″	MER -(6) TER -(3)
Single Weapon				
 1 to 4 stations	16° - 30°	24″	180″	Rack Exposed or Faired
 1 to 2 stations	16° - 72.5°	24″	180″	Rack Exposed or Faired

Figure 52 Geometry Limitations Applicable to Correlation Studies

APPENDIX I

This appendix contains the comparisons of the experimental values of the aerodynamic force or moment coefficients acting on a particular store configuration against values calculated by the equations defined at the top of each plot. These equations were developed from the multiple linear regression analysis program coded for the CDC 6600 computer.

The aerodynamic coefficients are indexed in Table VI, page 98. The coefficient comparisons are located within the appendix by page number for each Triple Ejector Rack (TER) store configuration. The aerodynamic coefficients for Multiple Ejector Rack (MER) store configurations are derived from the TER equations as described in Section 4.3.

TABLE VI INDEX TO COEFFICIENTS IN APPENDIX I

Triple Ejector Rack (TER) Configuration

STORE CONFIGURATION/COEFFICIENTS		C_N	C_Y	C_m	C_n	C_ℓ
Weapon Cluster + Rack + Pylon						
Outboard	Pages:	99-104	105-110	110-116	117-122	123-128
Inboard	Pages:	129-134	135-140	141-146	147-152	153-158
Weapon Cluster + Rack						
Outboard	Pages:	159-164	165-170	171-176	177-182	183 188
Inboard	Pages:	189-194	195-200	201-206	207-212	213-218
Single Weapon + Rack + Pylon						
Outboard	Pages:	219-224	225-230	231-236	237-242	243-248
Inboard			None - See Section 4.0			
Single Weapon + Rack						
Outboard	Pages:	249-254	255-260	261-266	267-272	273-278
Inboard			None - See Section 4.0			

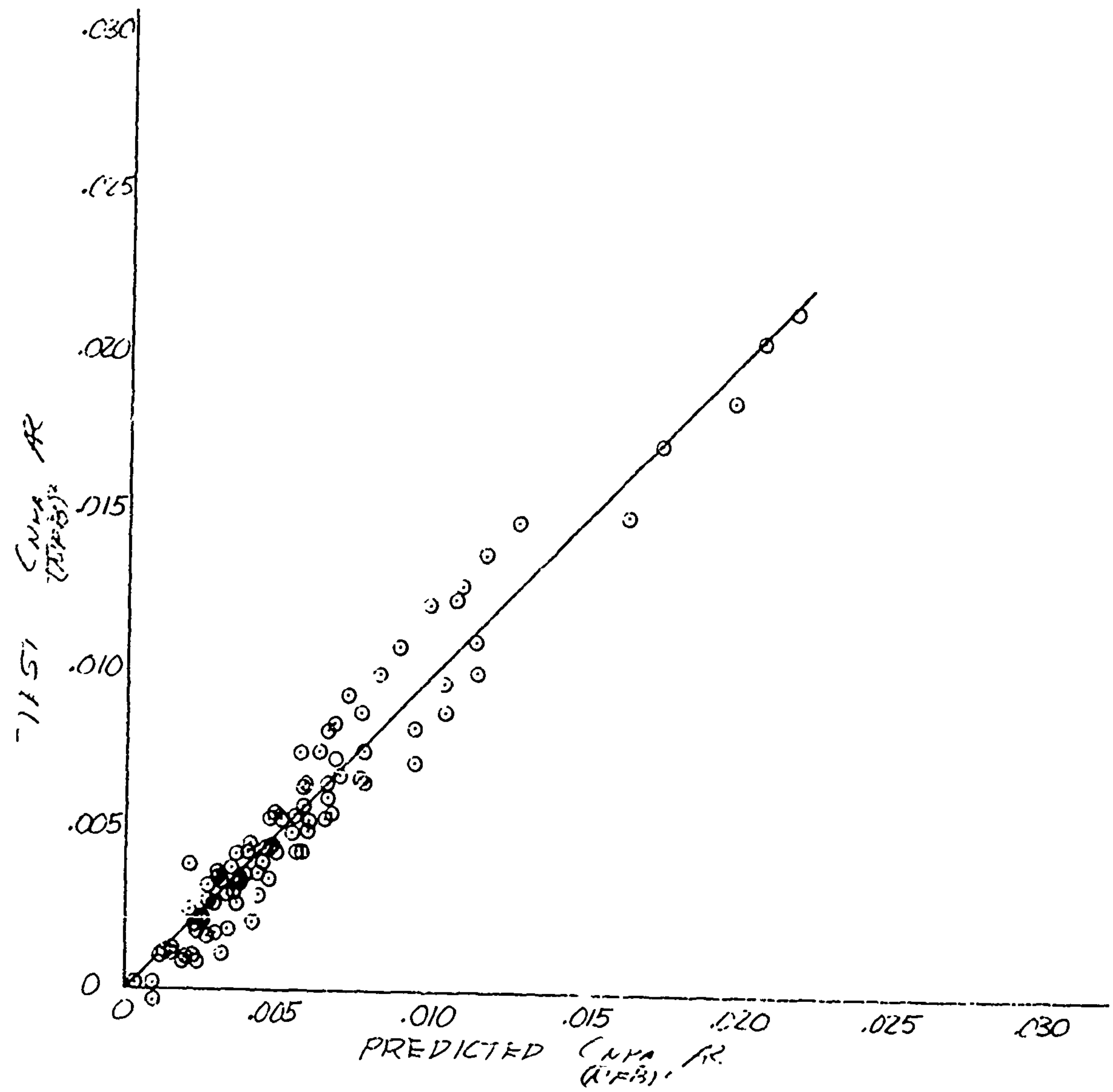
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = 16^{\circ},\ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{N_{PA}}}{NFB^2} AR = .052312 + .000190\,\ell - .003519D - .000039C$$
$$-.000177\Delta X + .0000126\,\frac{PA}{FA} \times FSPD - .003695M^2$$



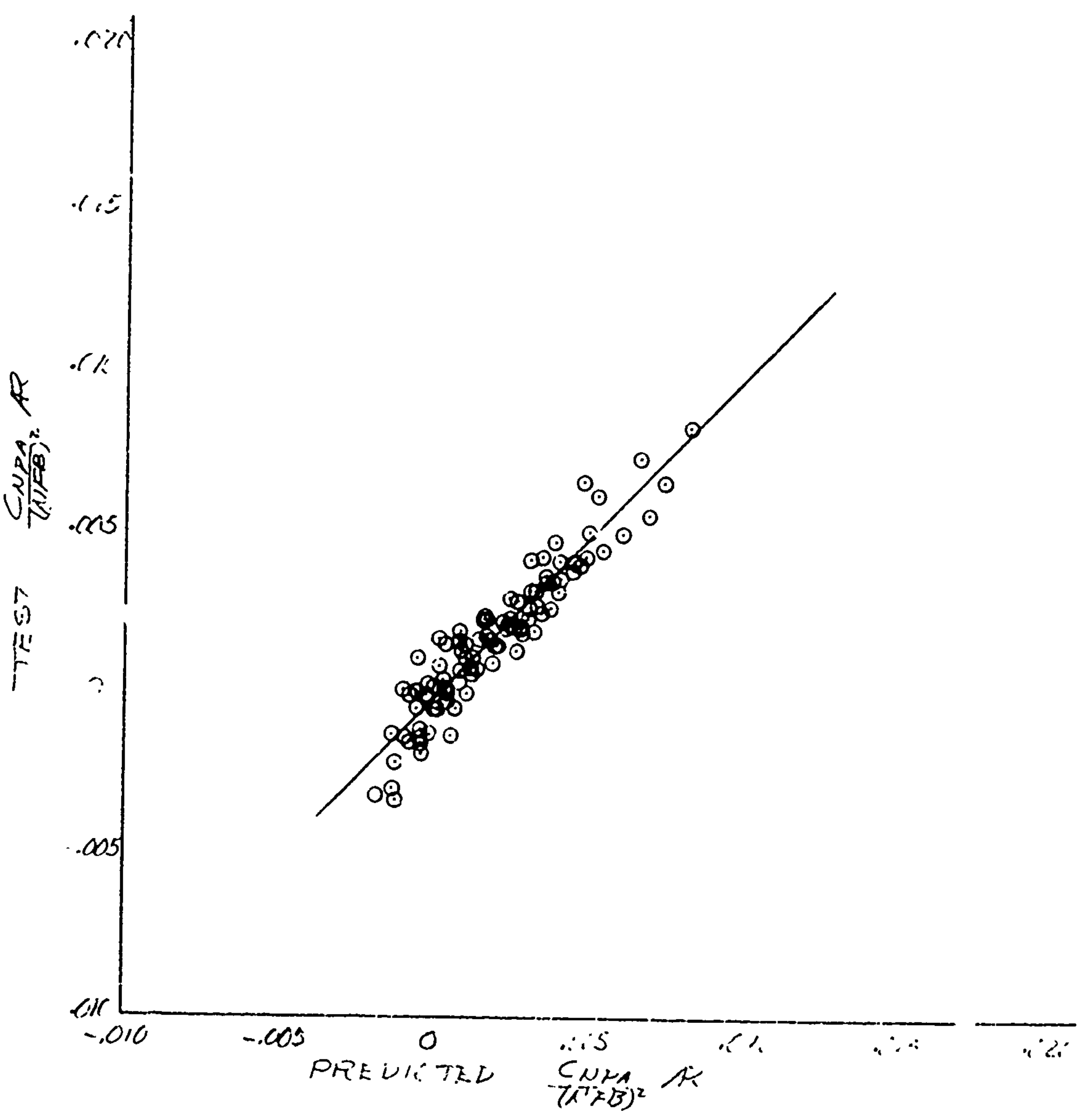
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = 6^\circ, \ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{N_{PA}}}{NFB^2} AR = .046517 + .000174\,\ell - .003249D - .000031C - .000165\Delta X + .0000055\,\frac{PA}{FA}\,x \cdot FSPD - .003019M^2$$



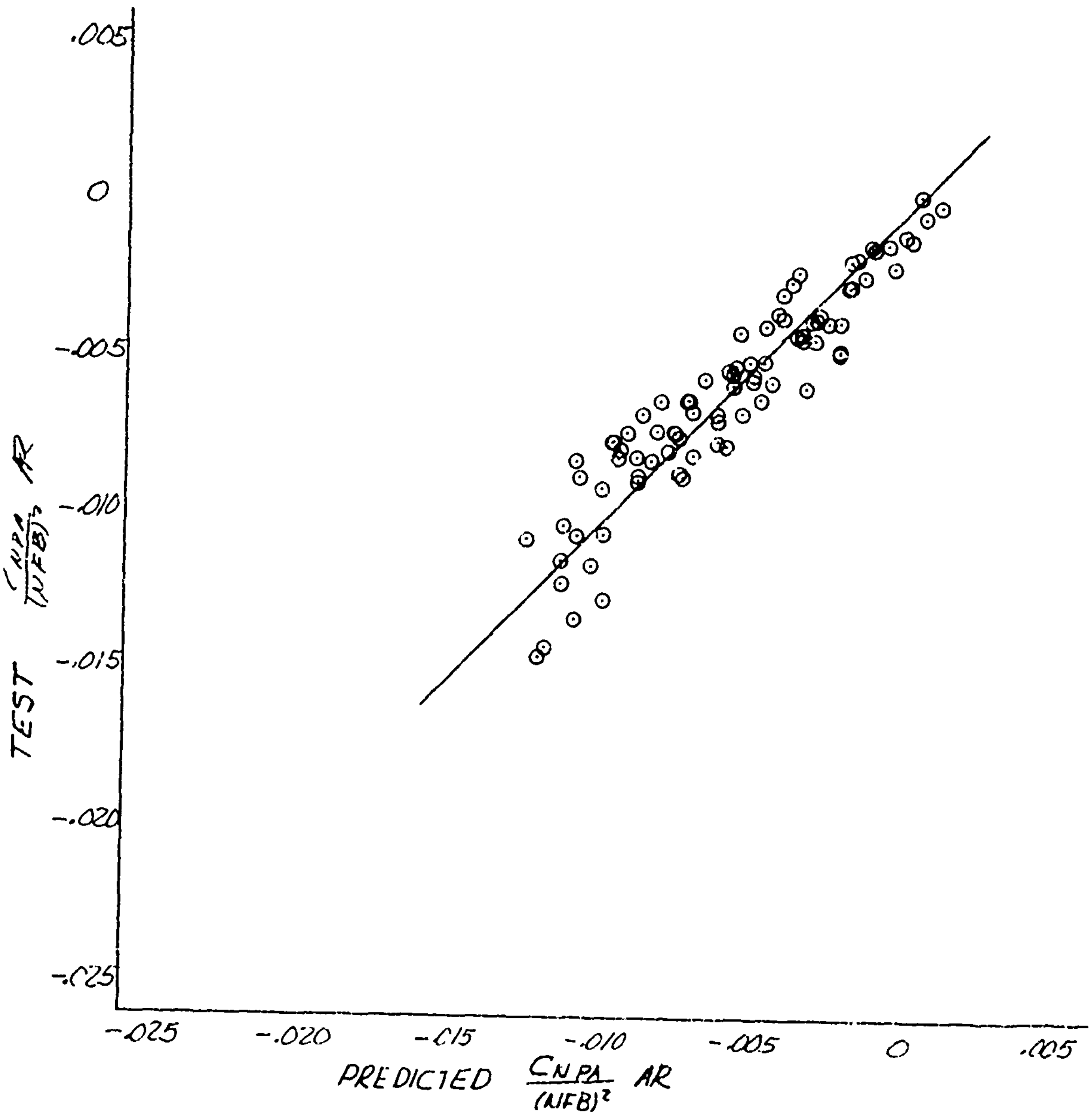
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = -4^{\circ}, \ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{N_{PA}}}{NFB^2} AR = .104971 + .000264\,\ell - .006963D - .000051C - .000156\Delta X - .0000016\,\frac{PA}{FA} \times FSPD - .014285M^2$$



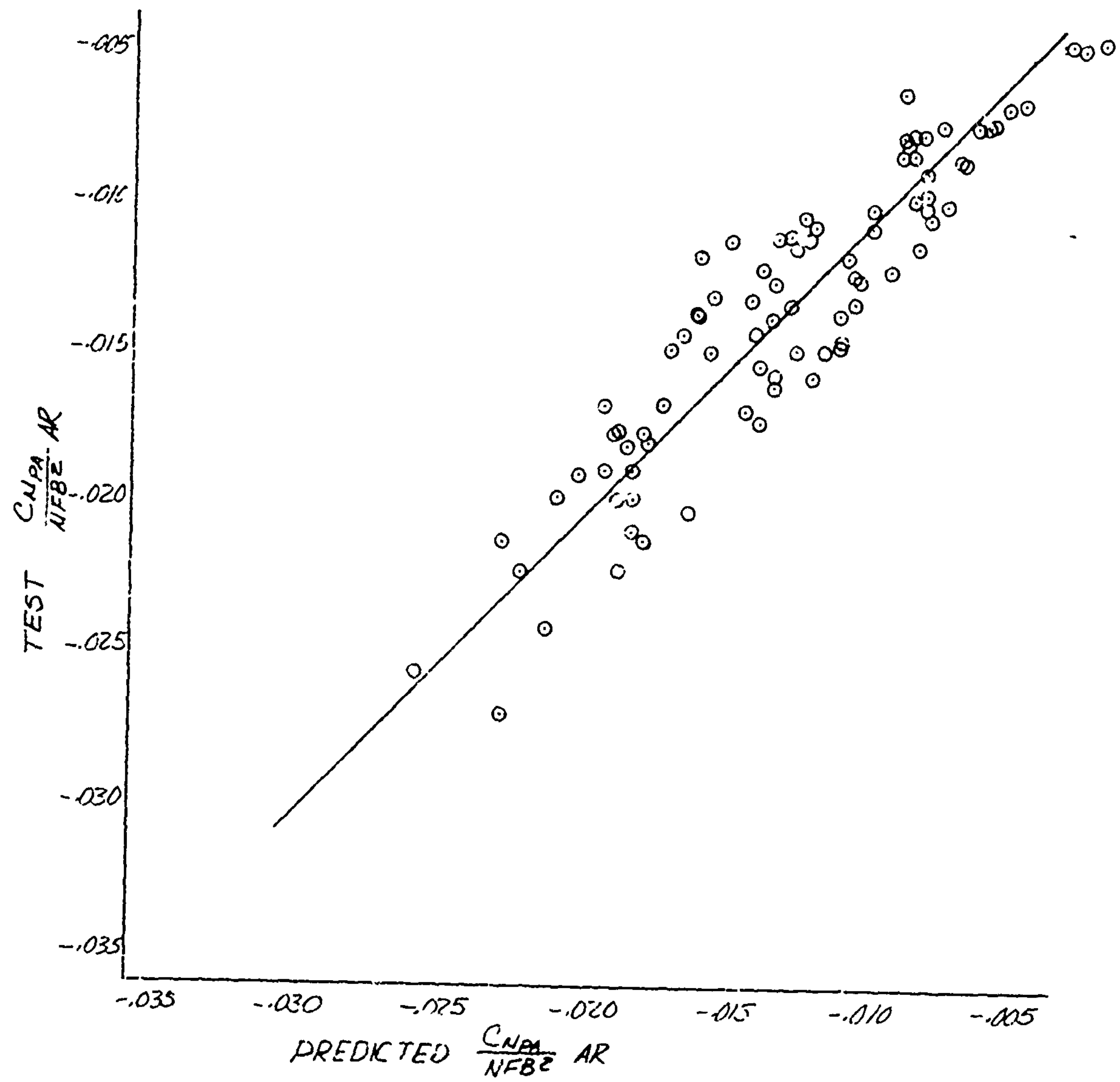
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = -9^{\circ}, \ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{N_{PA}}}{NFB^2} AR = .153000 + .000358\,\ell - .009864D - .000128C - .000246\Delta X - .0000060\,\frac{PA}{FA} \times FSPD - .018588M^2$$



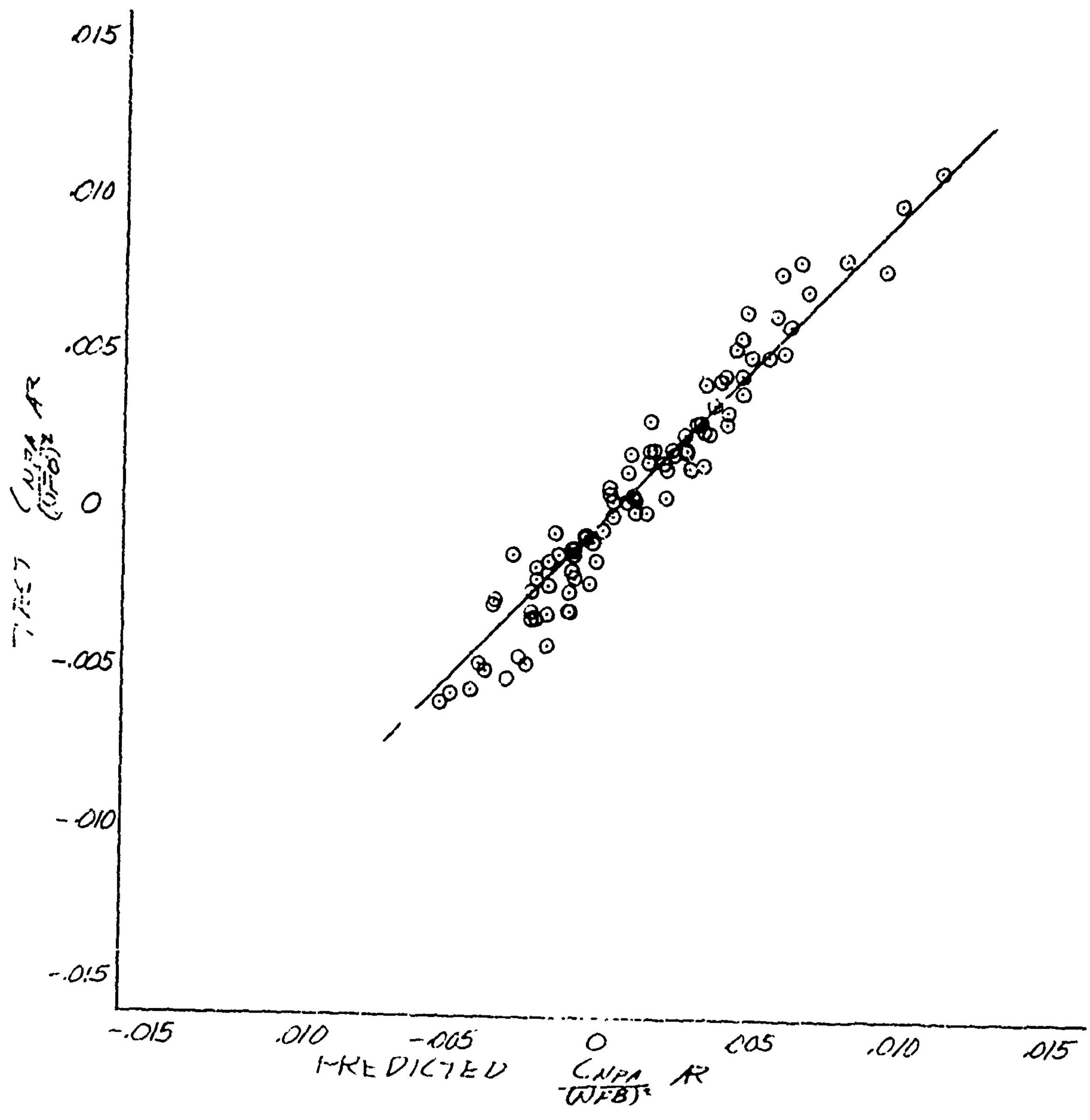
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \ \beta = +10^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{N_{PA}}}{NFB^2} AR = .095600 + .000296\,\ell - .006791D - .000035C - .000168\Delta X + .0000066\,\frac{PA}{FA} \times FSPD - .004721M^2$$



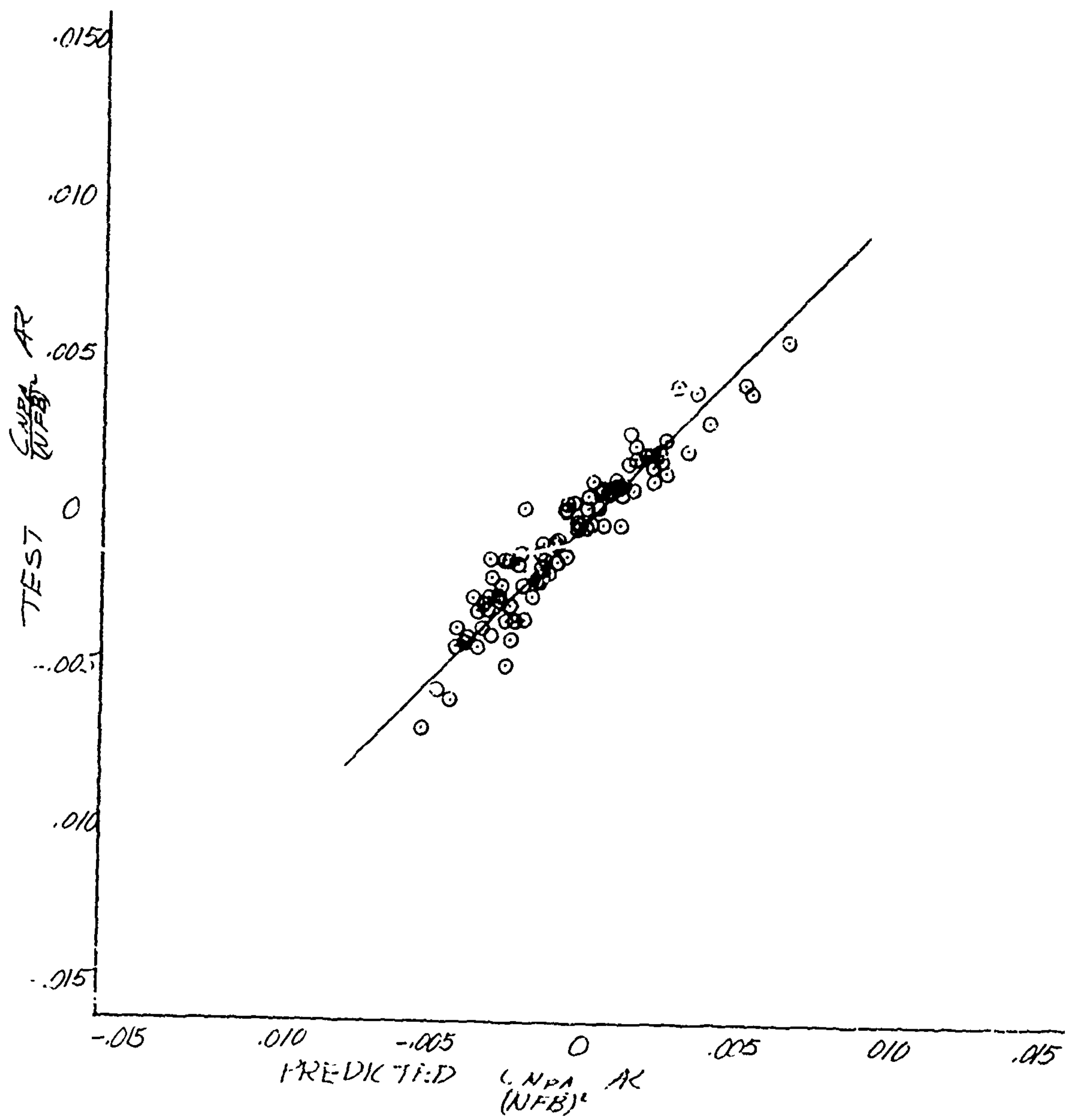
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
NORMAL FORCE COEFFICIENT

$$\alpha_{LOAD} = 6^{\circ}, \ \beta = -10^{\circ}$$

$$M = .60 - .95$$

$$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$$

$$\frac{C_{N_{PA}}}{NFB^2} AR = .080974 + .000240\ell - .005654D - .000045C - .000170\Delta X + .0000054 \frac{PA}{FA} \times FSPD - .004021M^2$$



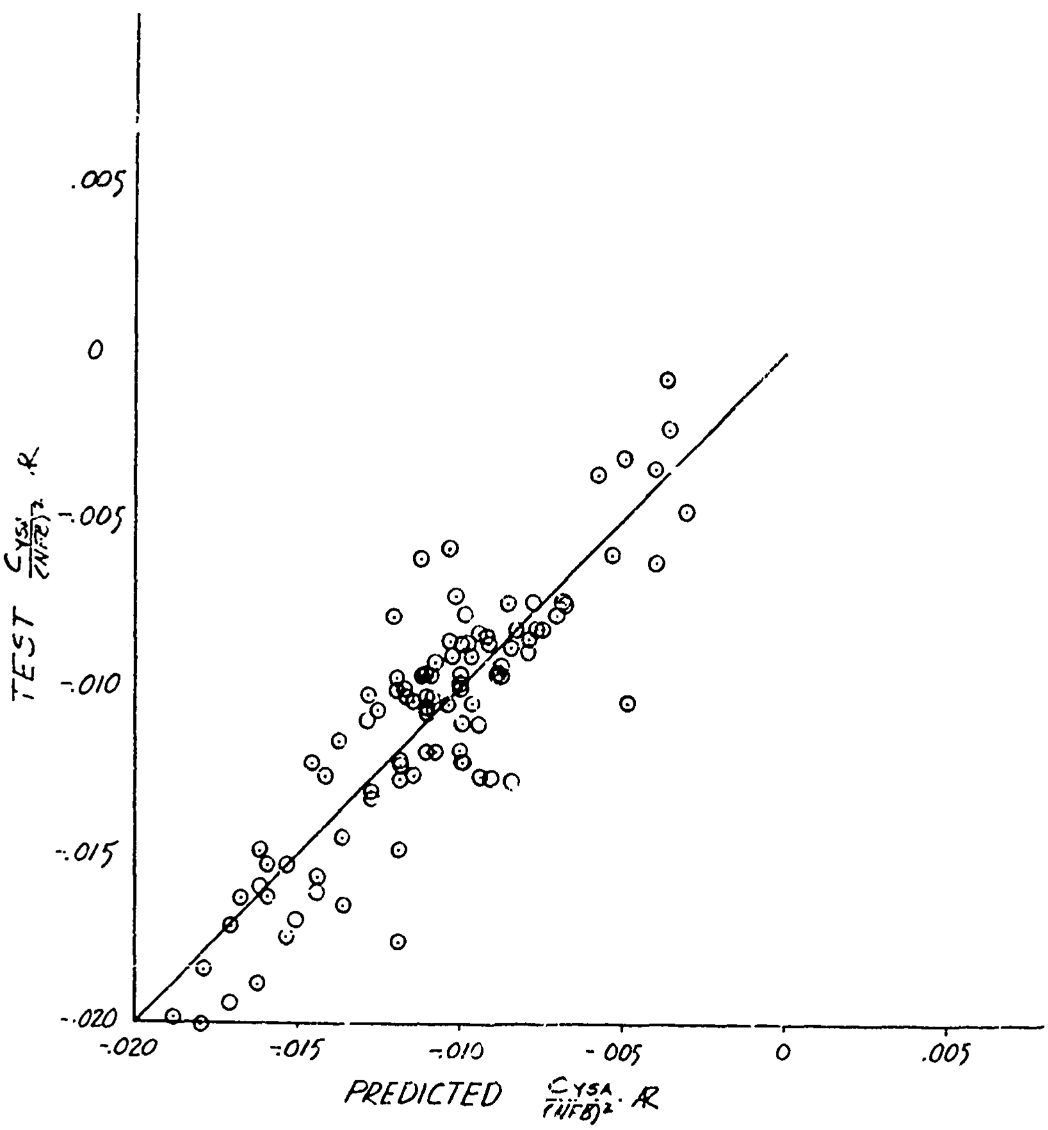
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = 16^{o}, \beta = 0^{o}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{o} - 72.5^{o}$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = .094227 + .000189\ell - .005186D - .000236C - .000274\Delta X - .000002 \frac{SA}{FA} \times FSPD - .003221M^2$$



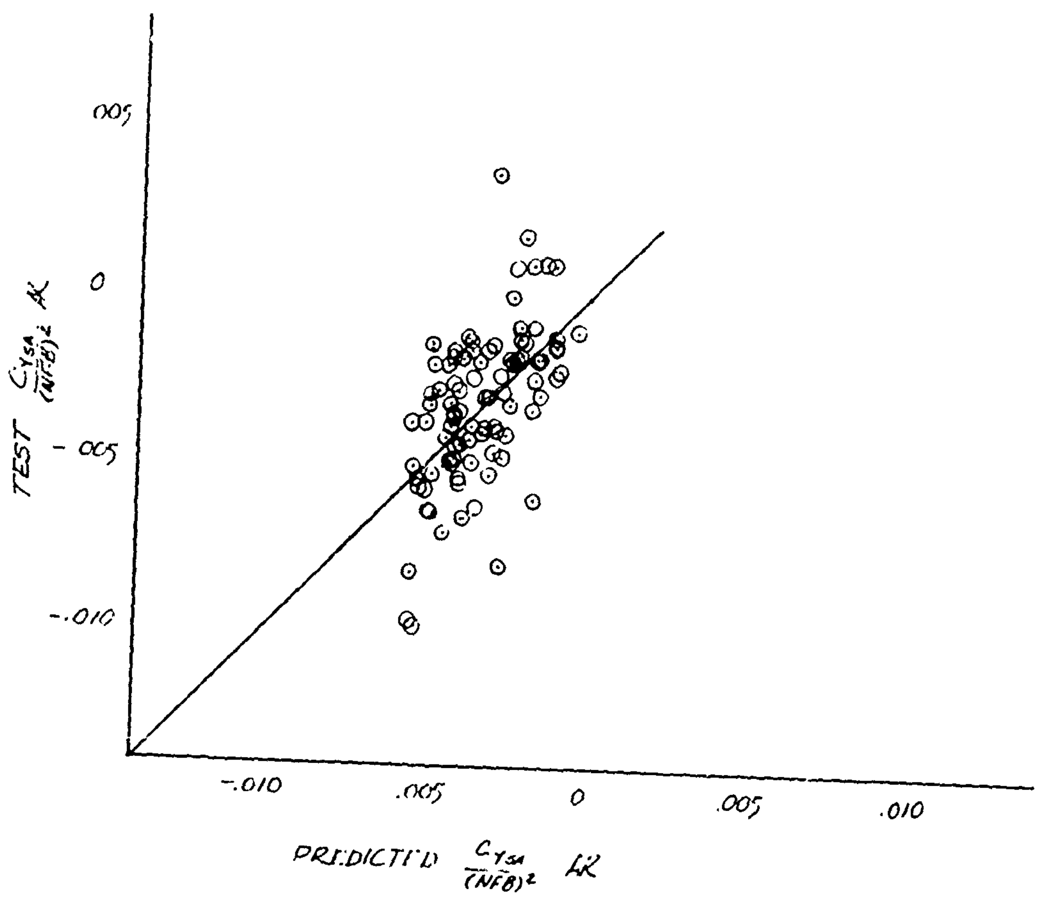
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = 6^\circ, \ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = .039732 + .000148\ell - .00226D - .000116C - .000192\Delta X - .000001 \frac{SA}{FA} \times FSPD - .002362M^2$$



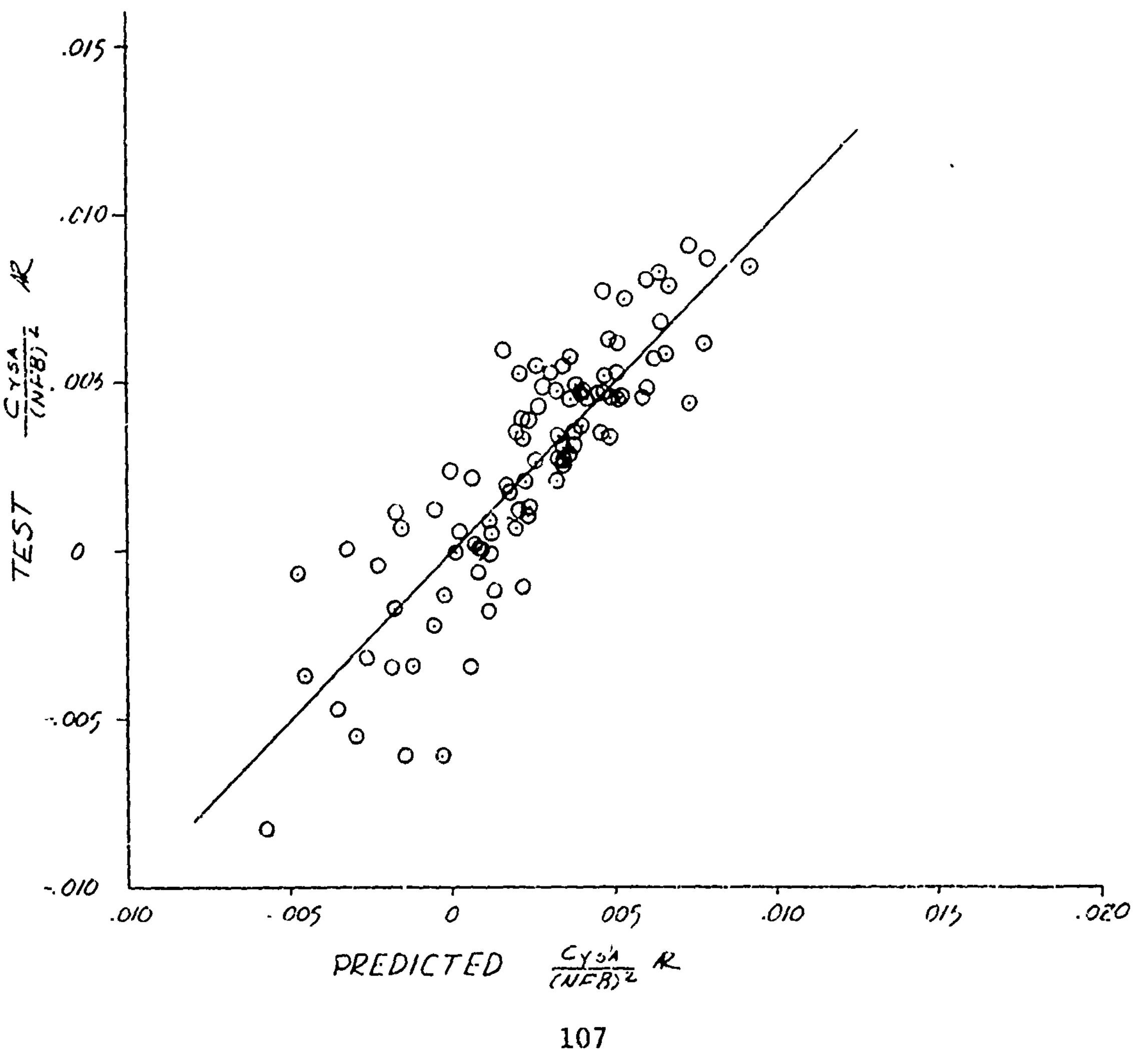
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = -4^{\circ}, \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = .055022 + .000147\ell - .004289D + .000077C + .000042\Delta X - .000001 \frac{SA}{FA} \times FSPD - .004536M^2$$



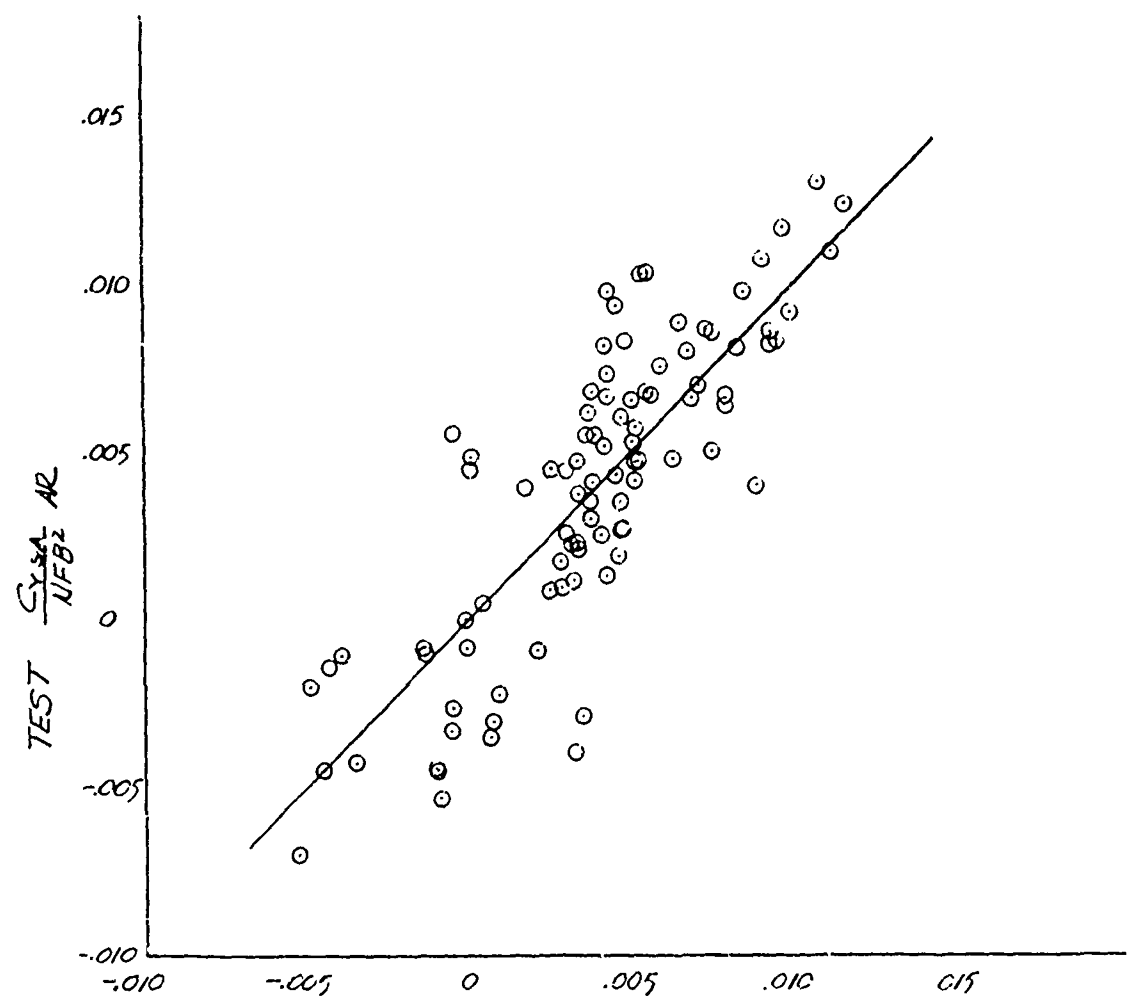
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = -9^{\circ}, \ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = .0409787 + .0001319\ell - .0037922D + .0001232C + .0001028\Delta X - .0000008 \frac{SA}{FA} \times FSPD - .0015085M^2$$



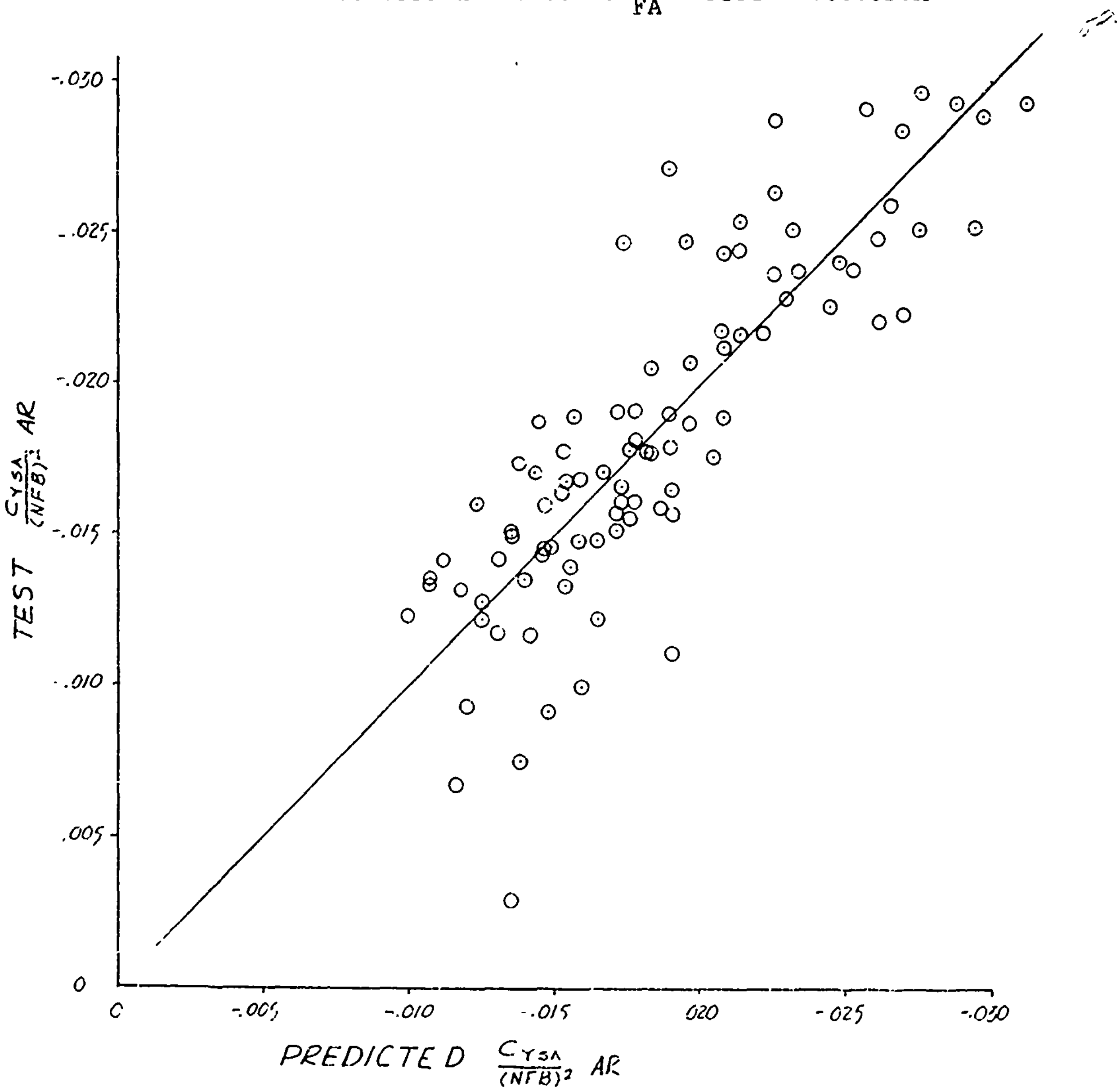
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = +6^\circ, \ \beta = +10^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = .087128 + .000162\ell - .006417D - .000066C - .000333\Delta X + .000010 \frac{SA}{FA} \times FSPD - .006626M^2$$



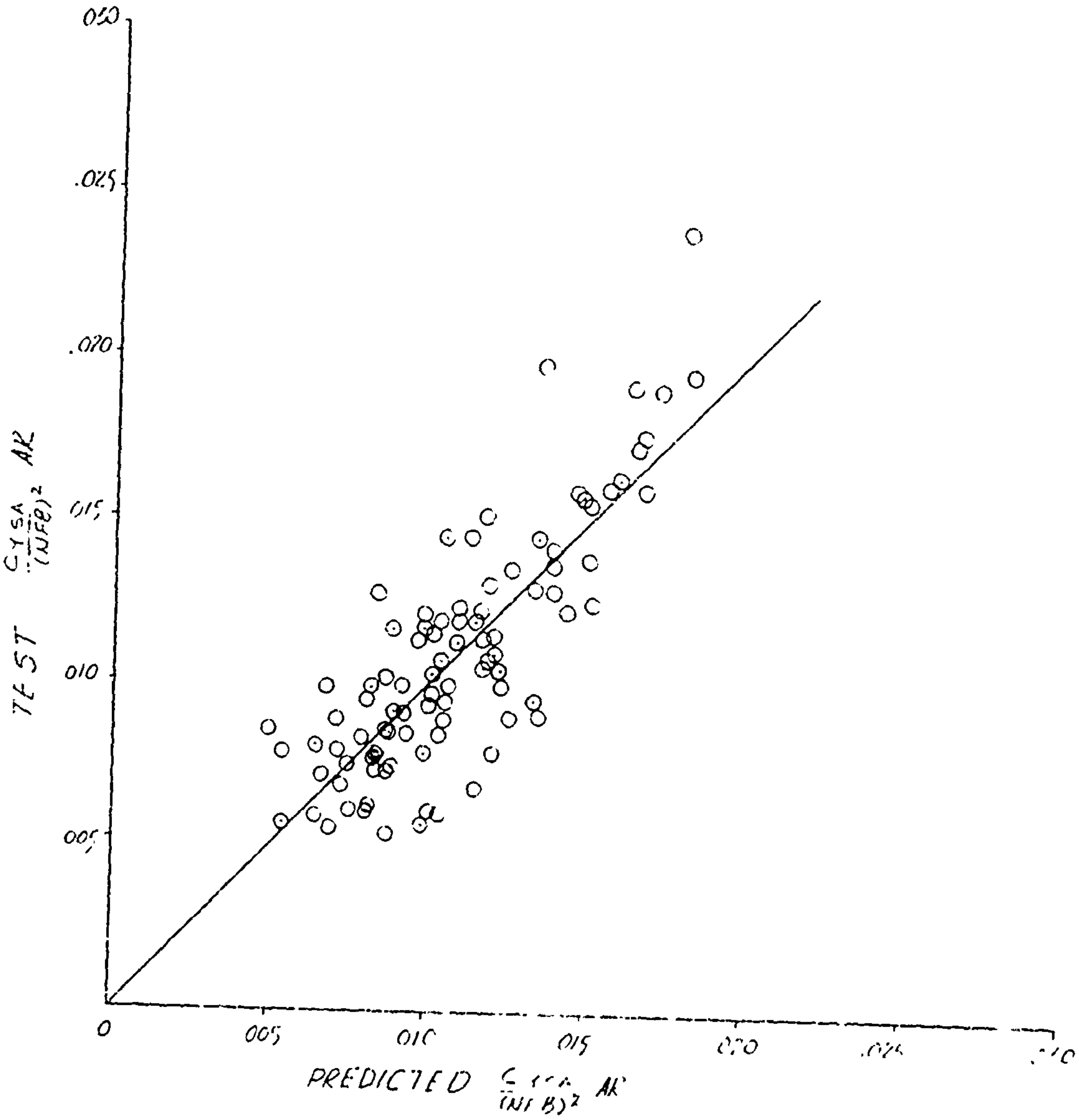
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = +6^{\circ},\ \beta = -10^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = -.039710 - .000004\ell + .003514D - .000091C - .000015\Delta X - .000003 \frac{SA}{FA} \times FSPD + .006264M^2$$



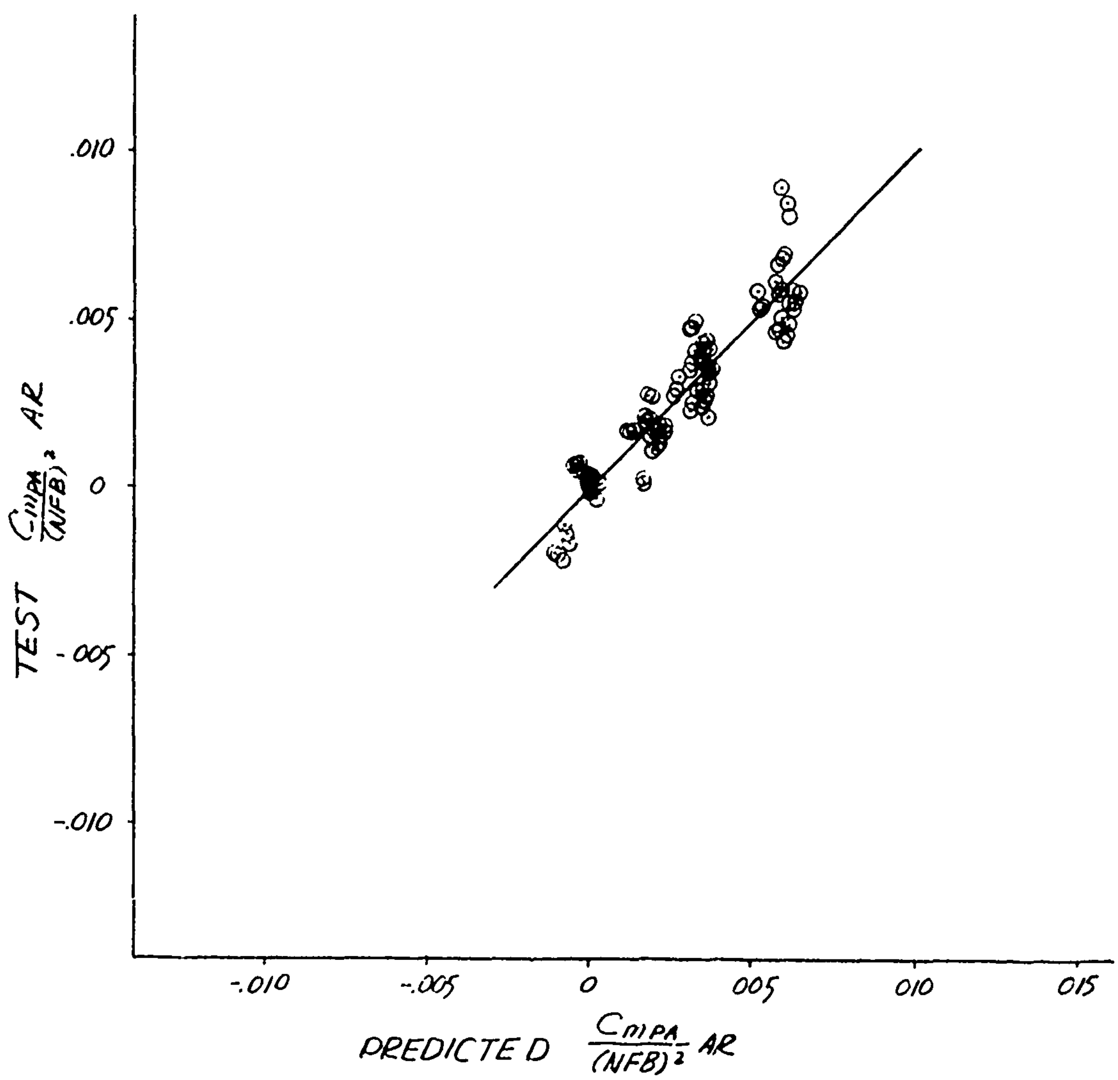
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
PITCHING MOMENT COEFFICIENT

$\alpha_{LOAD} = 16^{\circ}, \ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{m_{PA}}}{NFB^2} AR = -.051894 - .000184\ell + .004161D + .000010C + .0000594X - .000001 \frac{PA}{FA} \times FSPD - .000338M^2$$



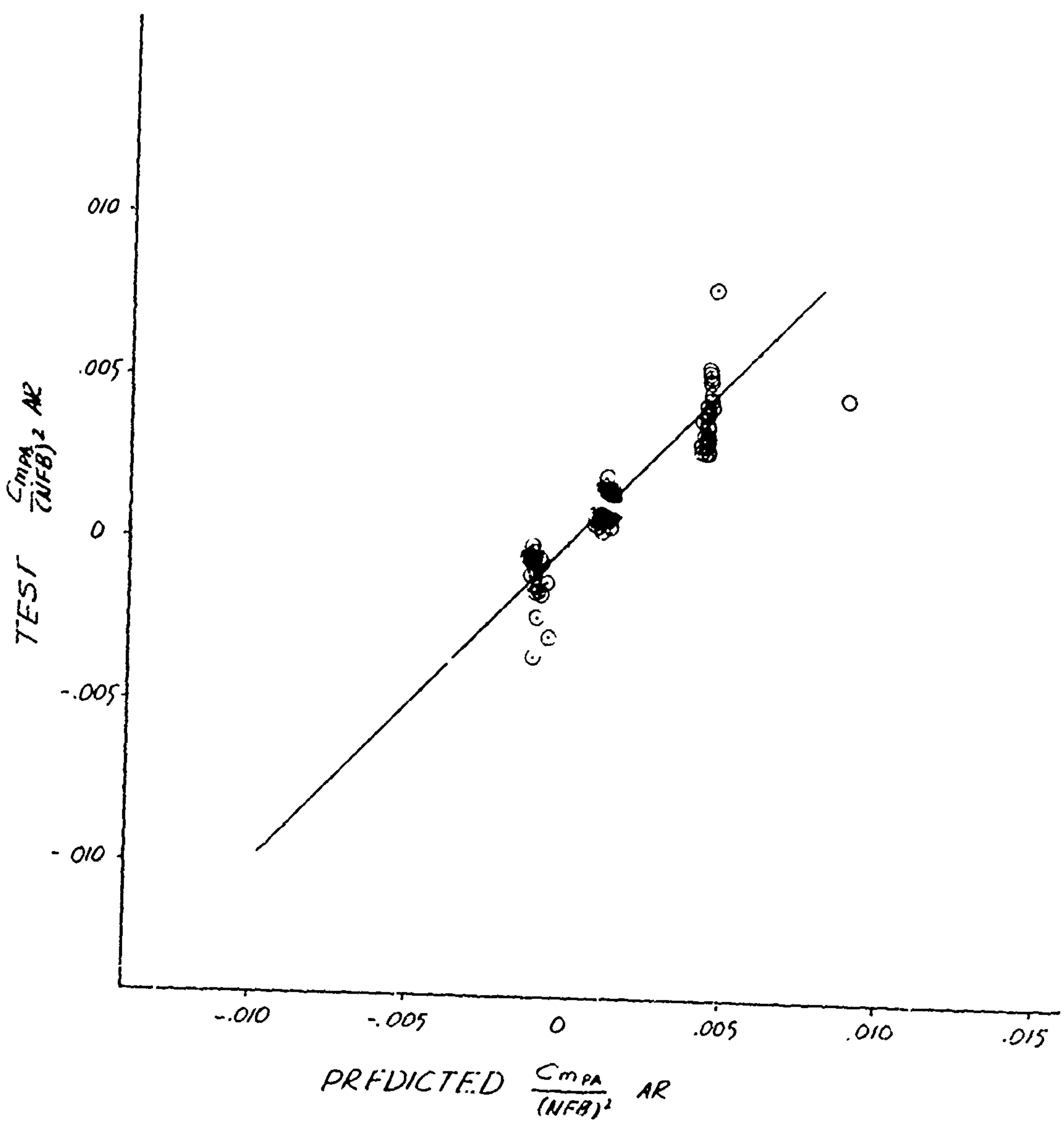
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
PITCHING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^\circ, \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{m_{PA}}}{NFB^2} AR = -.046446 - .000132\ell + .003595D - .000007C - .000017\Delta X + .0000004 \frac{PA}{FA} \times FSPD + .000389M^2$$



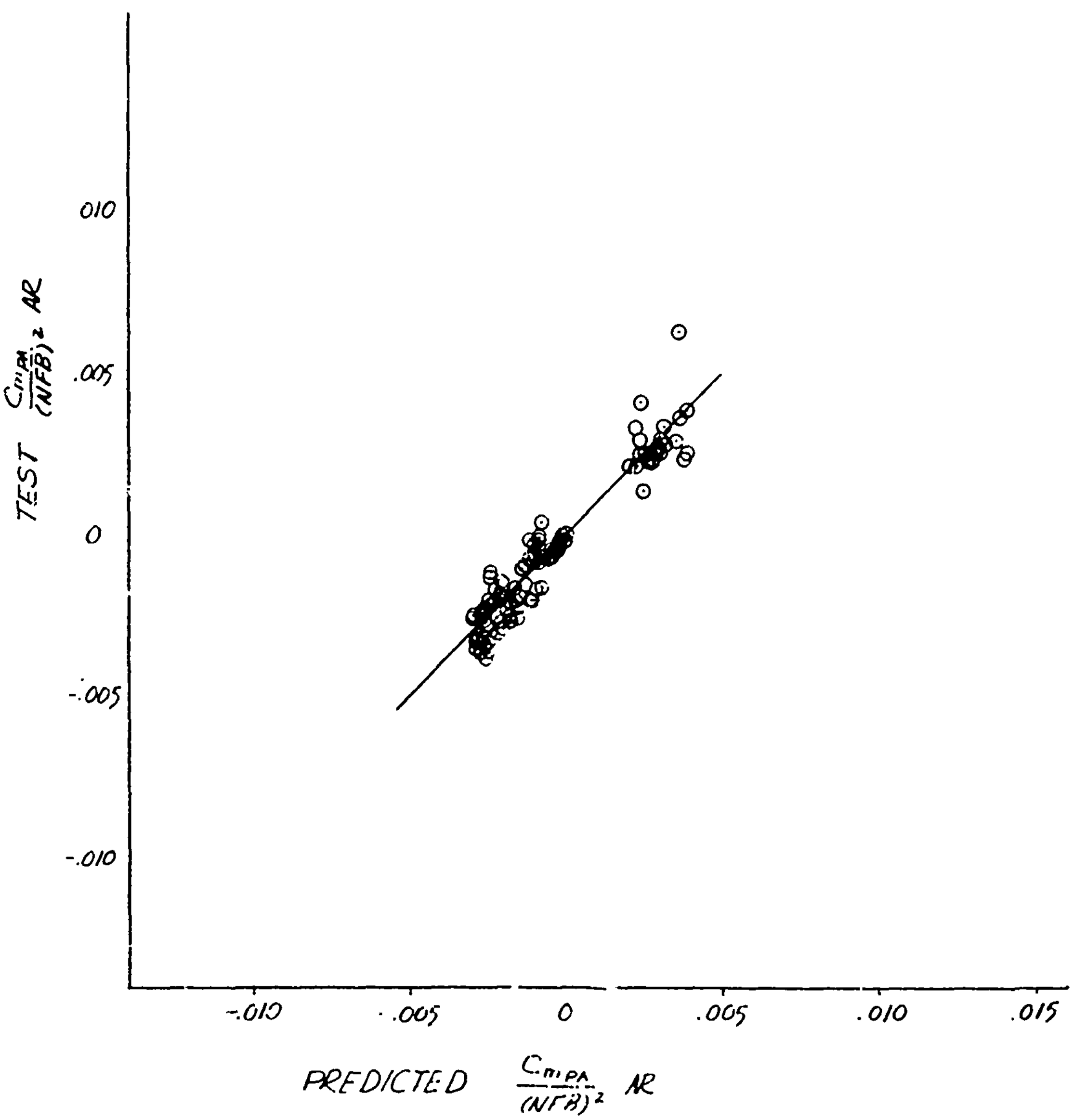
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
PITCHING MOMENT COEFFICIENT

$\alpha_{LOAD} = -4^{o}, \beta = 0^{o}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{o} - 72.5^{o}$

$$\frac{C_{m_{PA}}}{NFB^2} AR = -.068600 - .000070\ell + .005205D - .000092C - .000174\Delta X - .0000001 \frac{PA}{FA} \times FSPD + .000300M^2$$



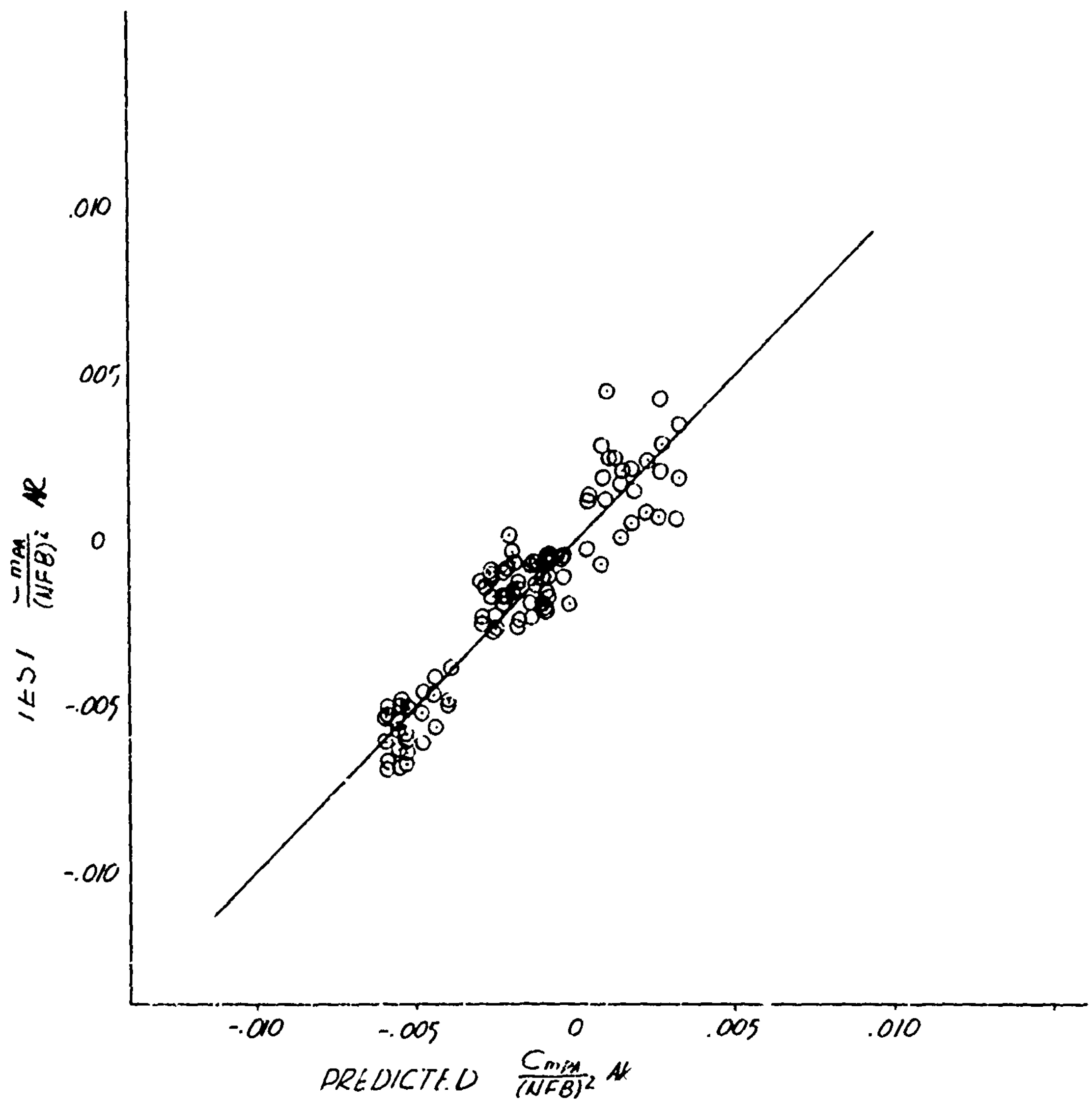
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
PITCHING MOMENT COEFFICIENT

$\alpha_{LOAD} = -9^{\circ},\ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{m_{PA}}}{NFB^2} AR = -.081475 - .000004\,\ell + .006119D - .000154C - .000299\Lambda X - .0000004\,\frac{PA}{FA} \times FSPD - .000097M^2$$



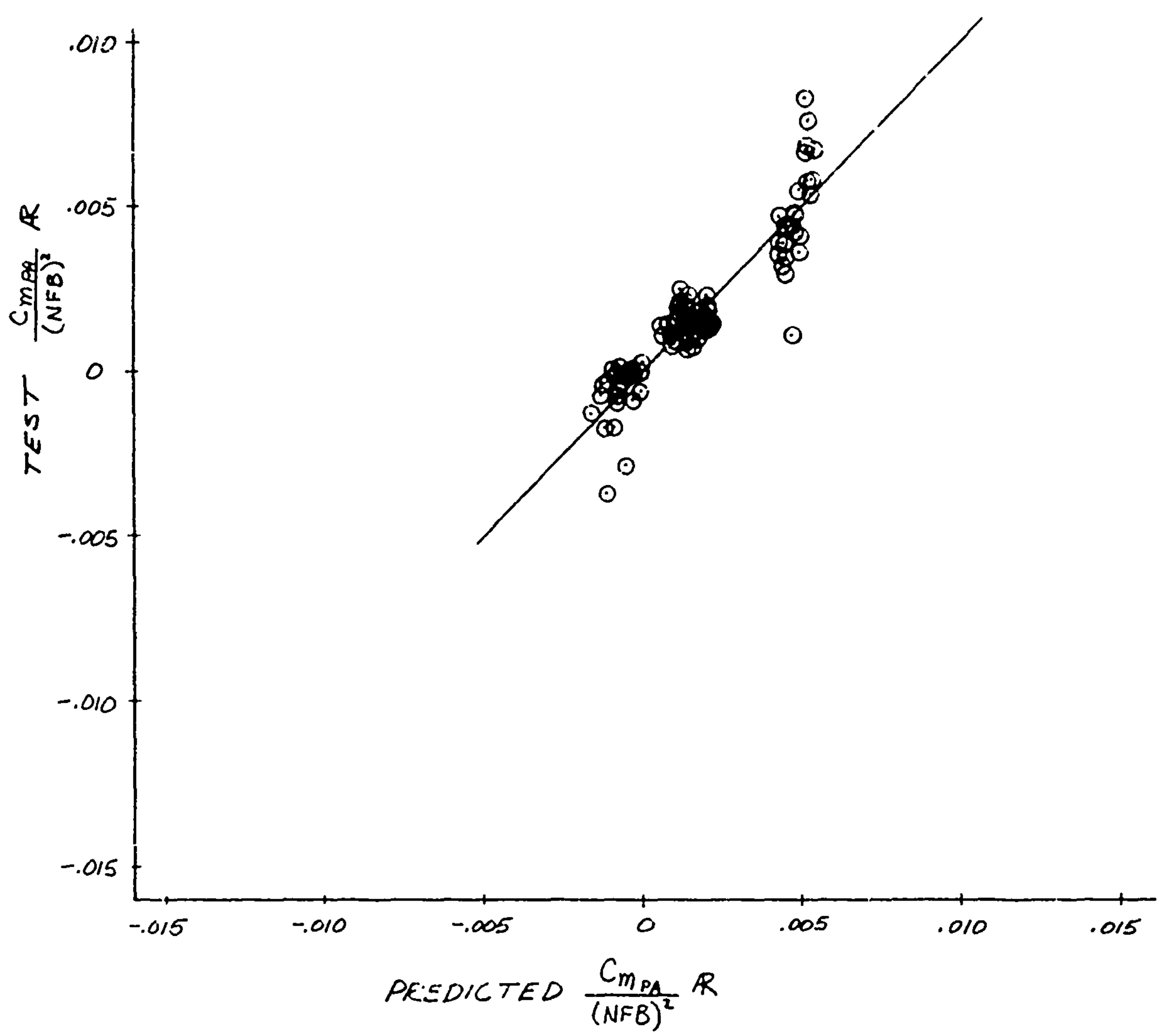
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
PITCHING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \ \beta = +10^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{m_{PA}}}{NFB^2} AR = -.052207 - .000137\ell + .003983D - .000009C - .000017\Delta X - .0000006 \frac{PA}{FA} \times FSPD + .001490M^2$$



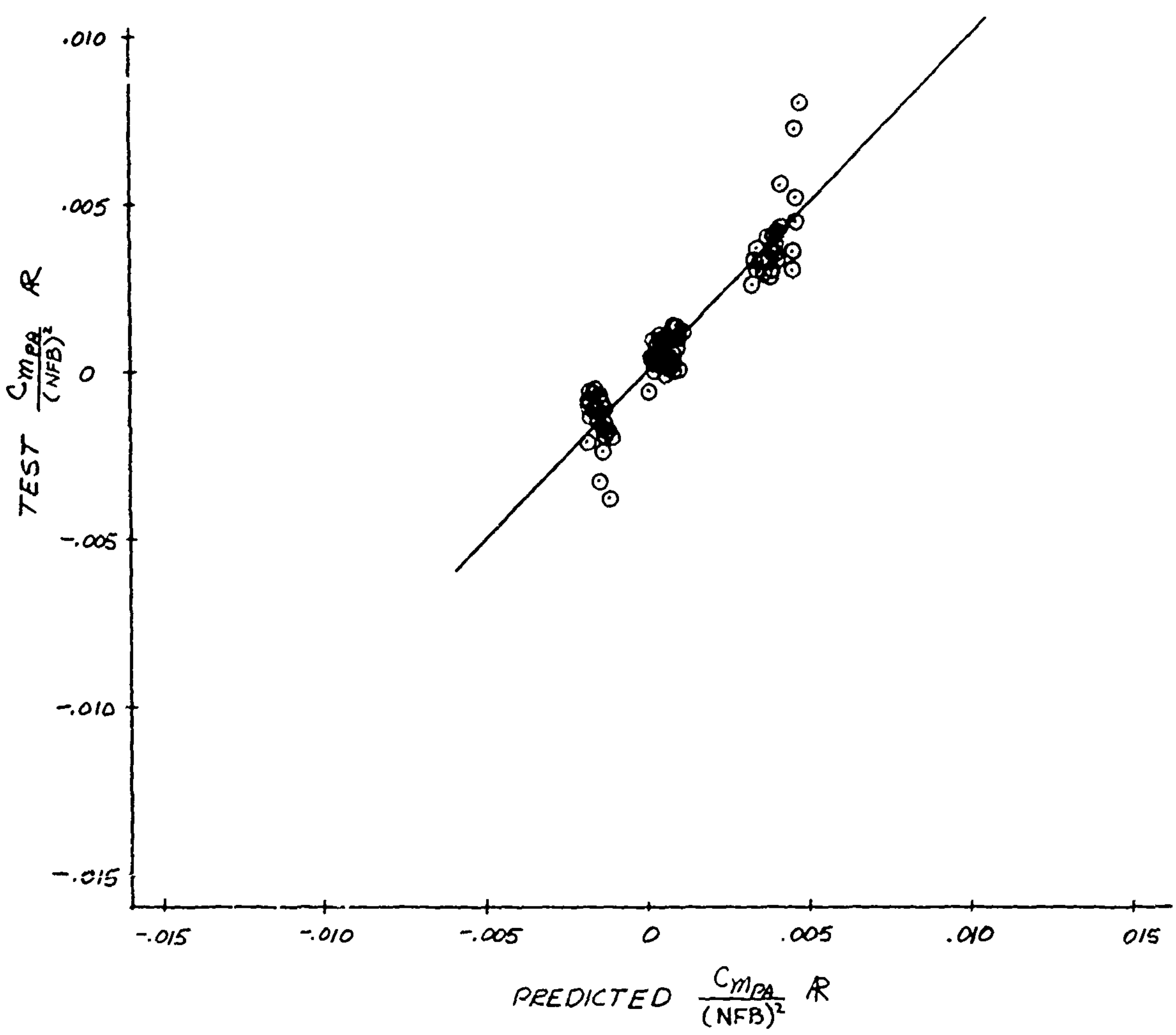
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
PITCHING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \beta = -10^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{m_{PA}}}{NFB^2} AR = -.044344 - .000119\ell + .003631D - .000037C - .000030\Delta X - .0000012 \frac{PA}{FA} \times FSPD + .000293M^2$$



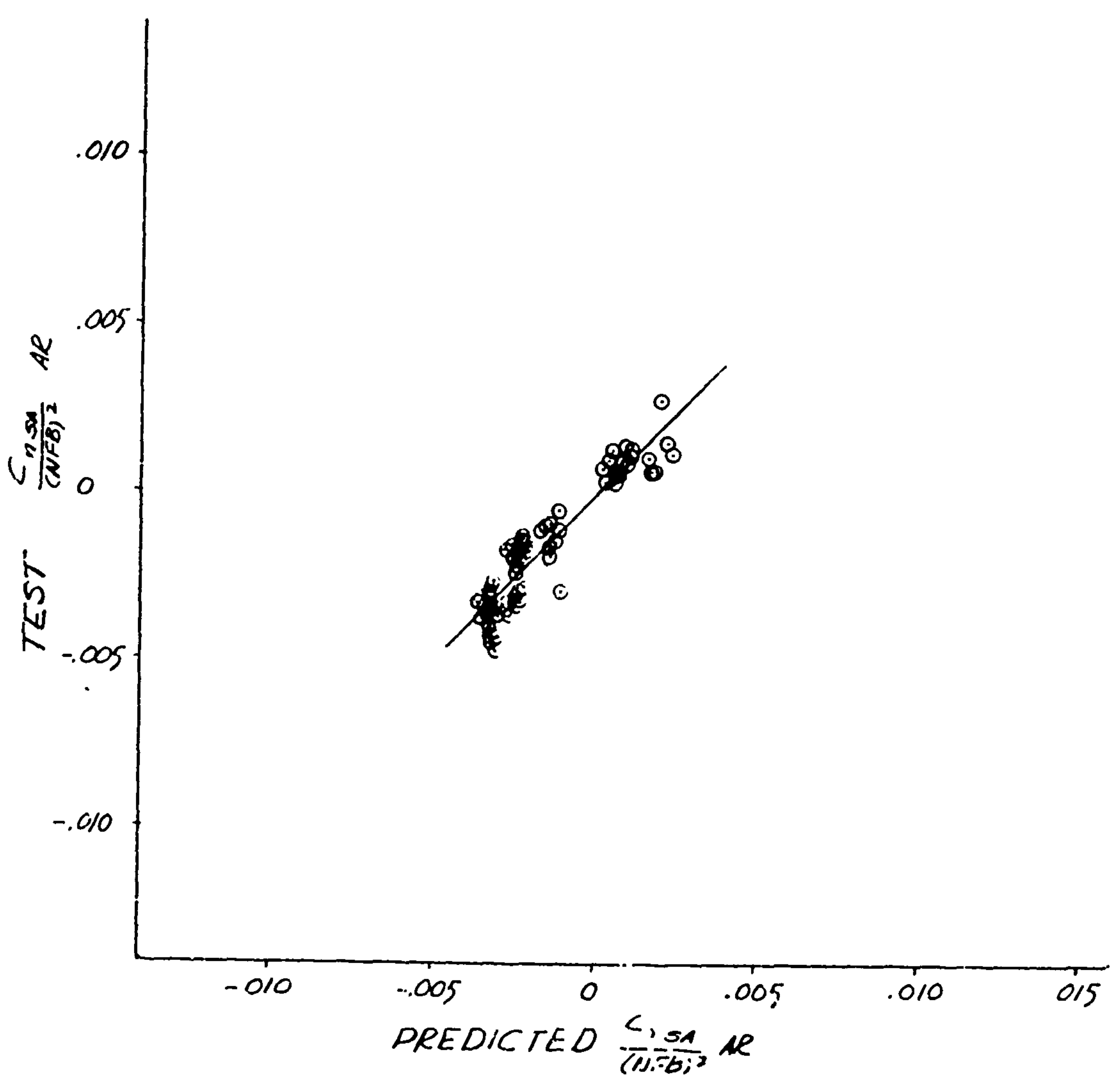
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = 16^\circ, \ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{n_{SA}}}{NFB^2} AR = -.045114 + .000001\ell + .002706D - .000018C - .000047\Delta X + .000002 \frac{SA}{FA} \times FSPD - .000524M^2$$



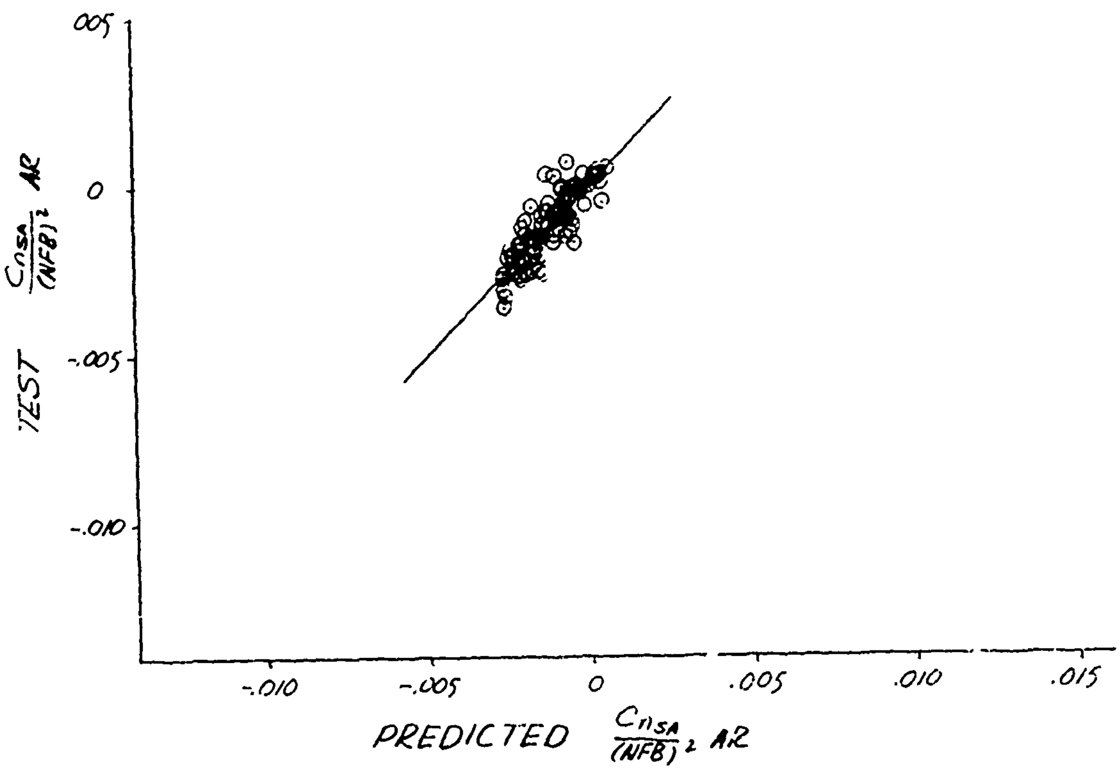
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^\circ, \ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{n_{SA}}}{NFB^2} AR = -.018915 + .000011\ell + .001322D - .000029C$$
$$-.000051\Delta X - .0000004 \frac{SA}{FA} \times FSPD - .001880M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON

Outboard

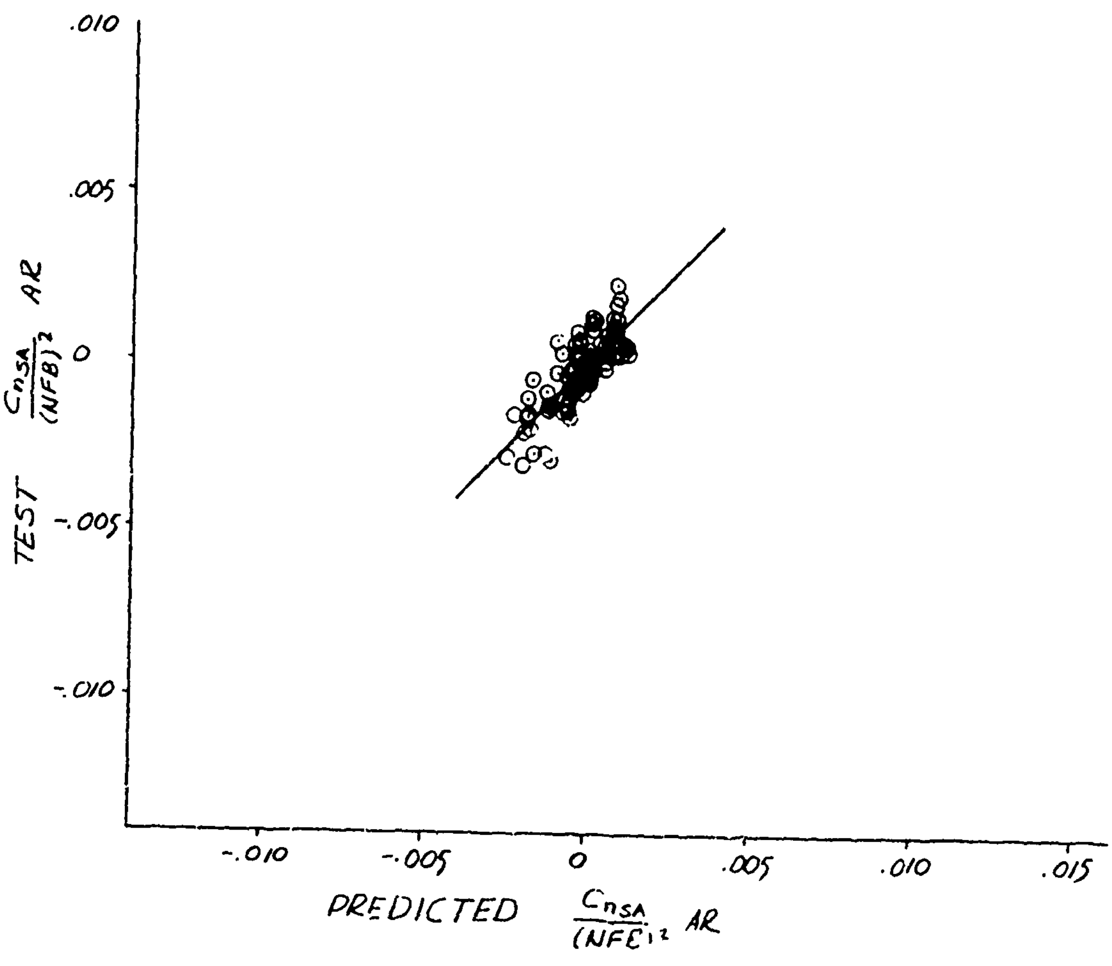
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = -4^\circ, \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{n_{SA}}}{NFB^2} AR = .023739 + .000042\ell - .001670D + .000016C + .000022\Delta X - .0000003 \frac{SA}{FA} \times FSPD - .002644M^2$$



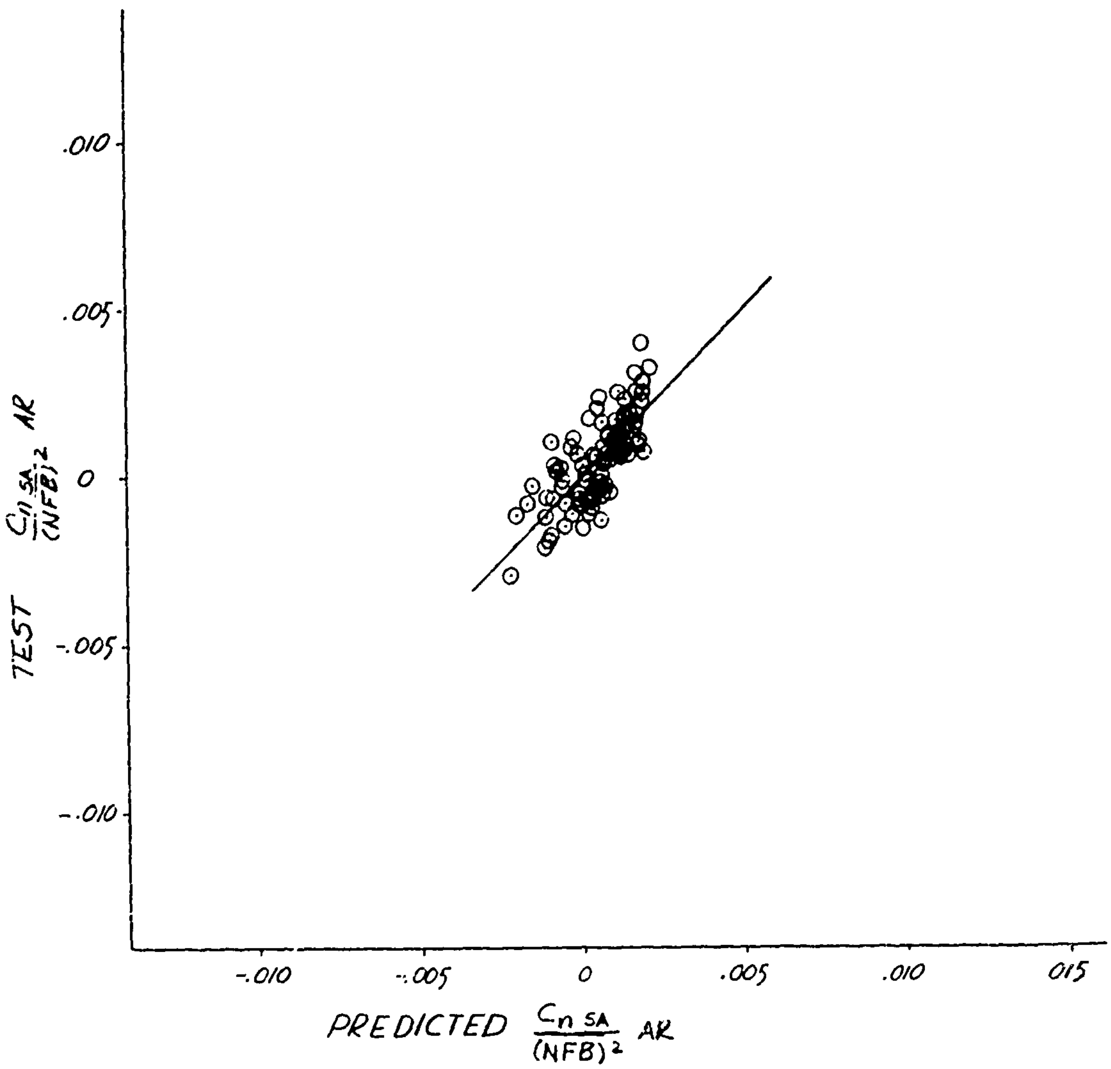
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = -9^\circ, \ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{n_{SA}}}{NFB^2} AR = .021740 + .000019\ell - .001619D + .000042C + .0000614X - .000001 \frac{SA}{FA} \times FSPD - .001981M^2$$



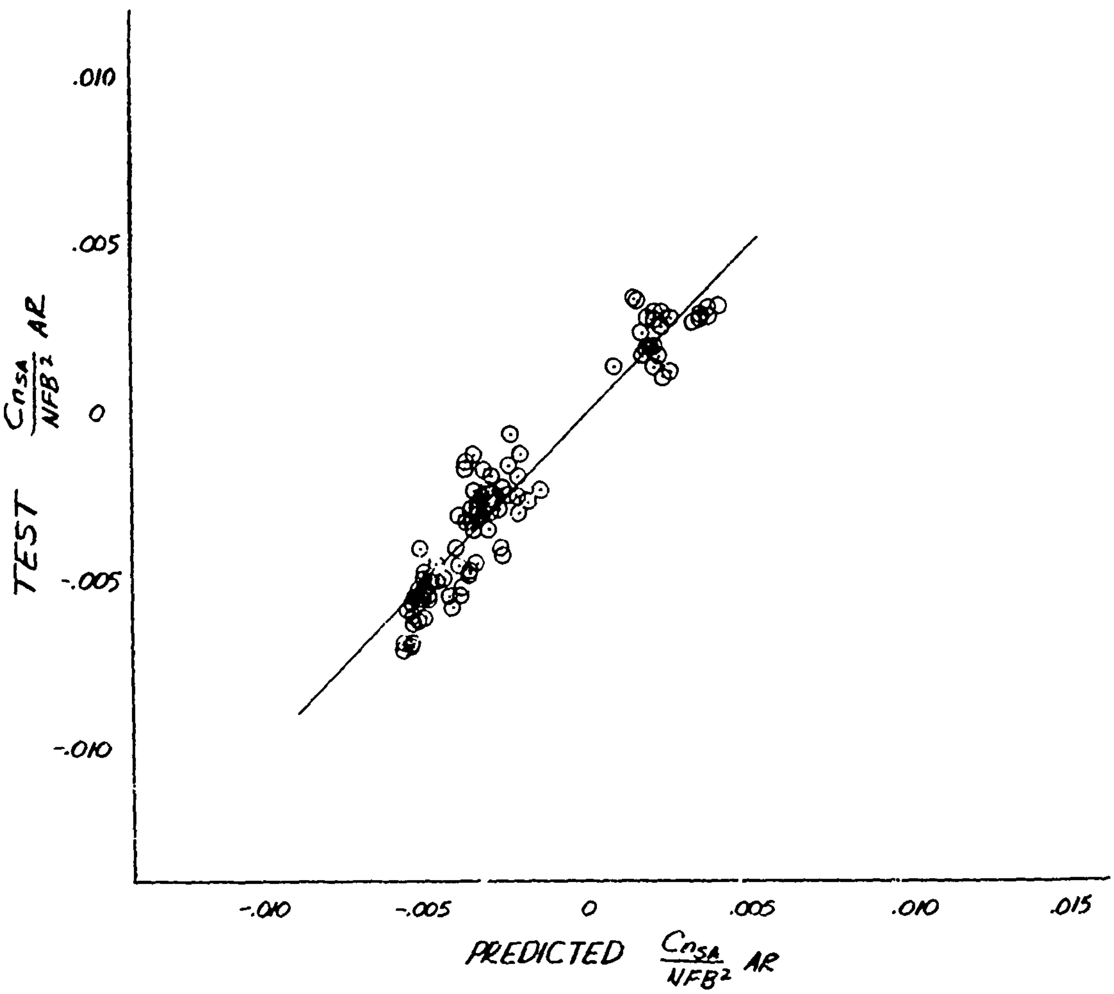
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \beta = +10^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{n_{SA}}}{NFB^2} AR = -.061530 + .000053\,\ell + .003718D - .000056C - .000123\Delta X + .0000019\,\frac{SA}{FA} \times FSPD - .000985M^2$$



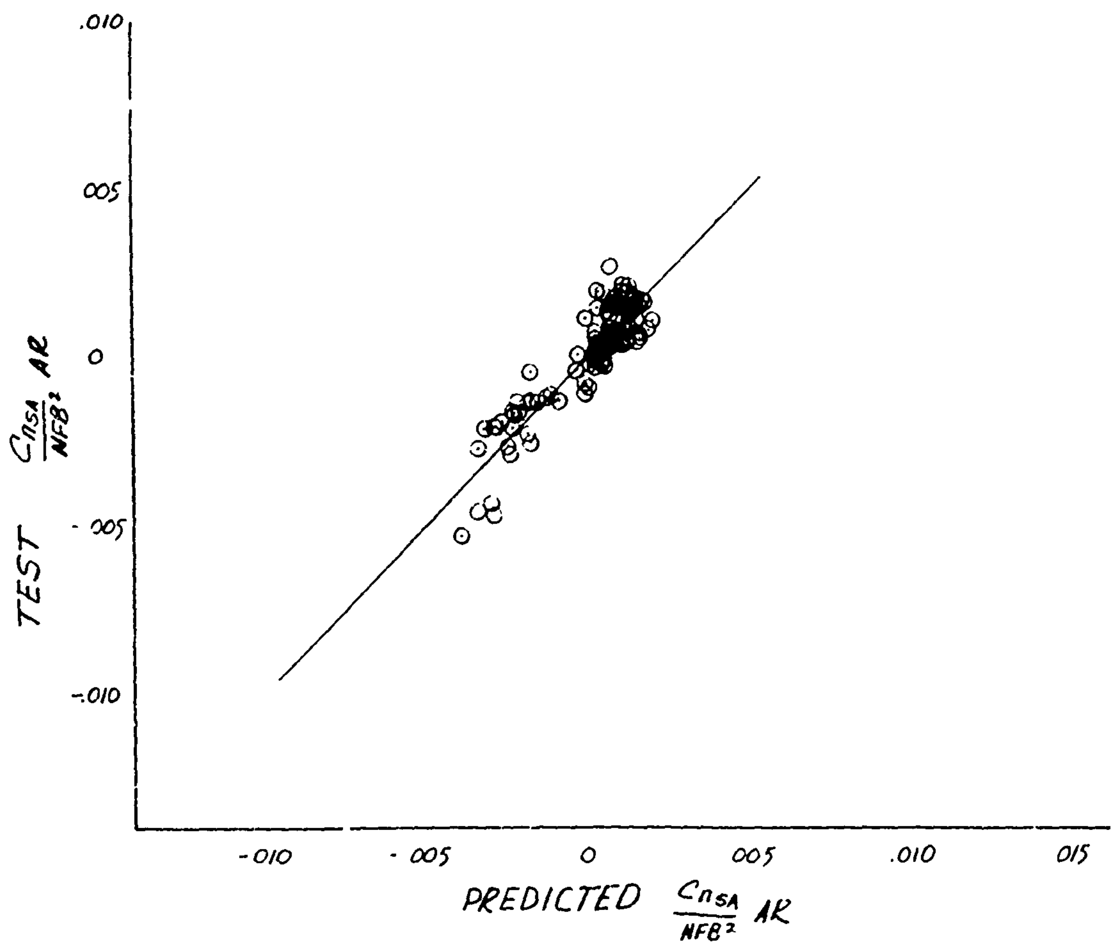
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \ \beta = -10^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{n_{SA}}}{NFB^2} AR = .028859 - .0000014\ell - .001456D - .000014C - .0000048\Delta X - .0000024 \frac{SA}{FA} \times FSPD - .002011M^2$$



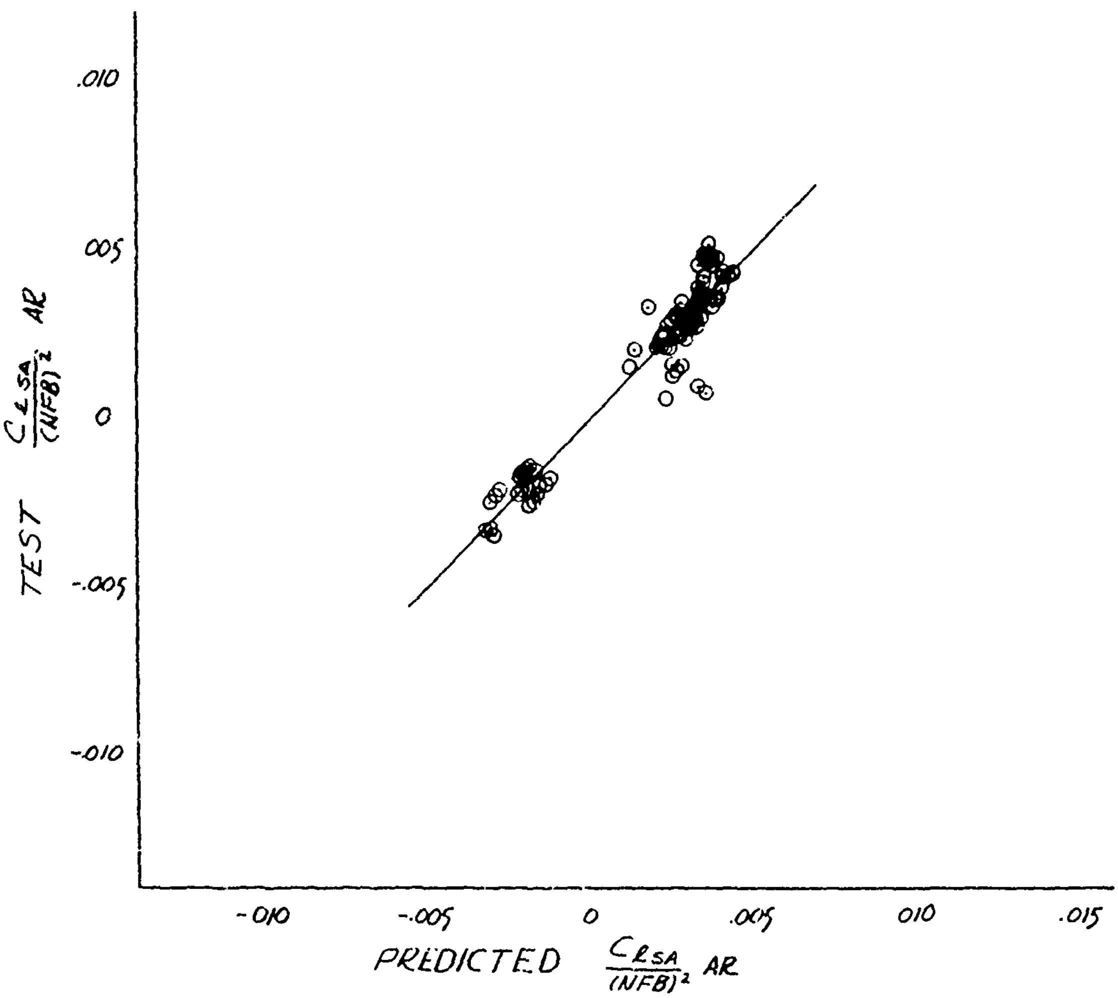
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
ROLLING MOMENT COEFFICIENT

$\alpha_{LOAD} = 16^\circ,\ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

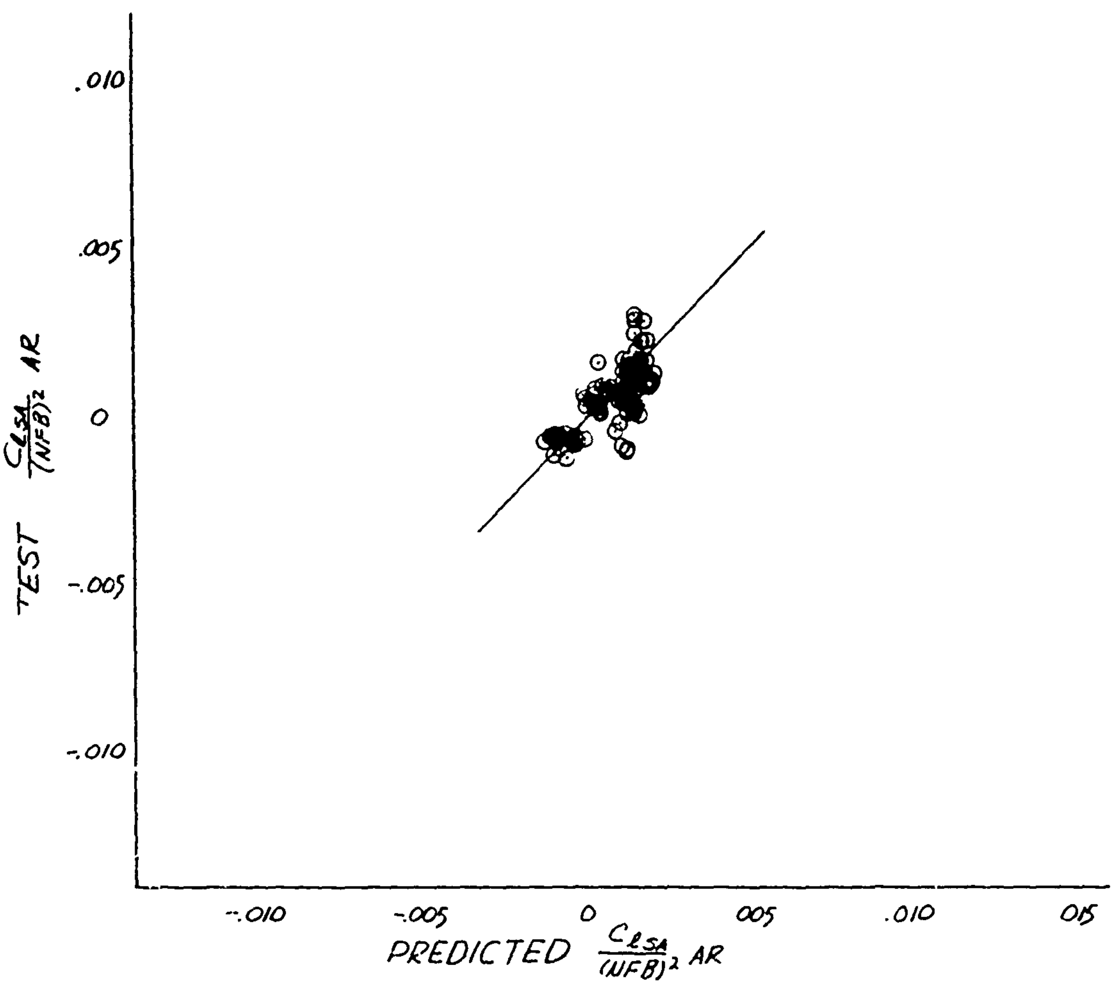
$$\frac{C_{\ell SA}}{NFB^2} AR = .024005 - .000061\ell - .001348D + .000042C + .000042\Delta X + .0000002 \frac{SA}{FA} \times FSPD + .000535M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
ROLLING MOMENT COEFFICIENT

$$\alpha_{LOAD} = 6^\circ,\ \beta = 0^\circ$$
$$M = .60 - .95$$
$$\Lambda_{LE} = 16^\circ - 72.5^\circ$$

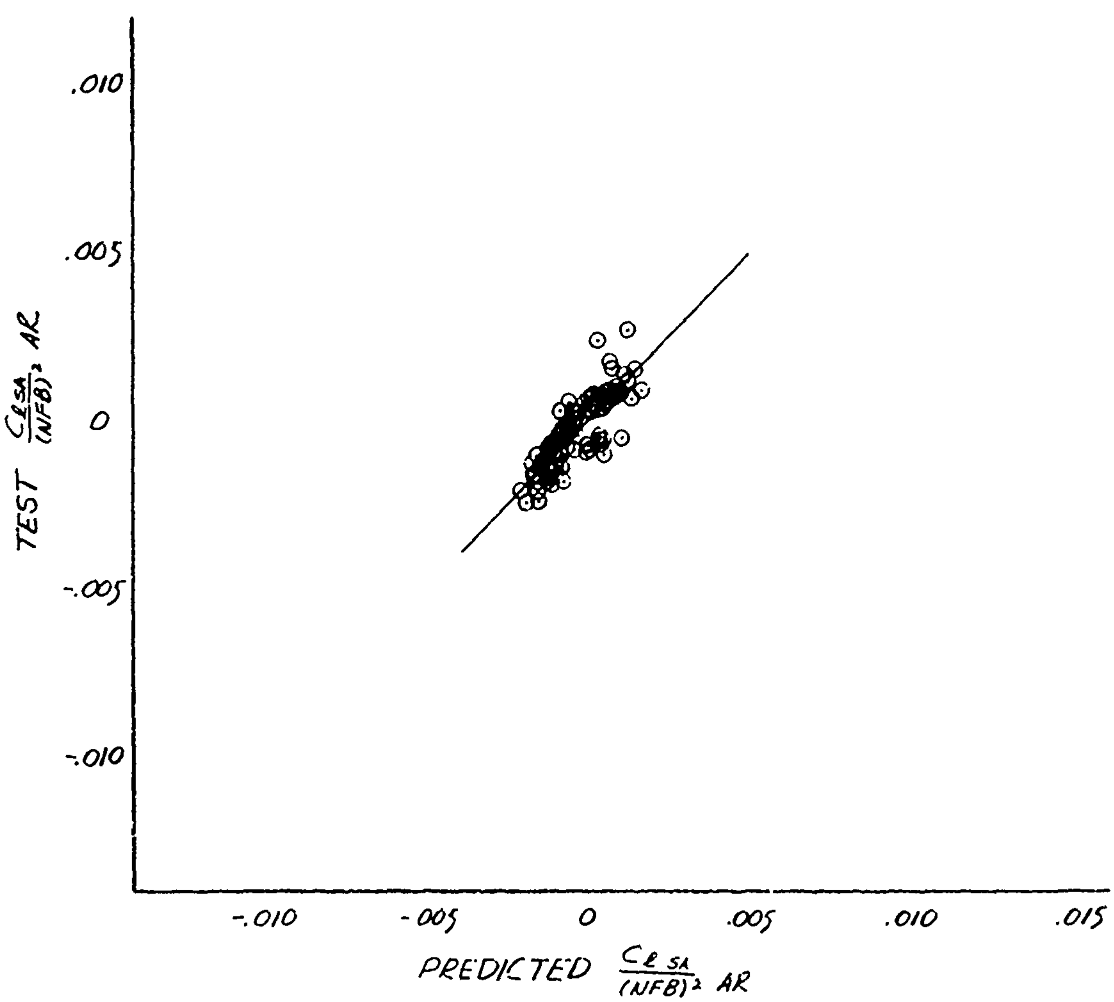
$$\frac{C_{\ell_{SA}}}{NFB^2} AR = -.014099 - .000079\ell + .000870D + .000046C + .000059\delta X + .0000012 \frac{SA}{FA} \times FSPD + .000716M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
ROLLING MOMENT COEFFICIENT

$$\alpha_{LOAD} = -4^{\circ},\ \beta = 0^{\circ}$$
$$M = .60 - .95$$
$$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$$

$$\frac{C_{\ell SA}}{NFB^2} AR = -.047025 - .000063\,\ell + .003143D - .000012C + .0000034X + .00000001\,\frac{SA}{FA} \times FSPD + .001300M^2$$



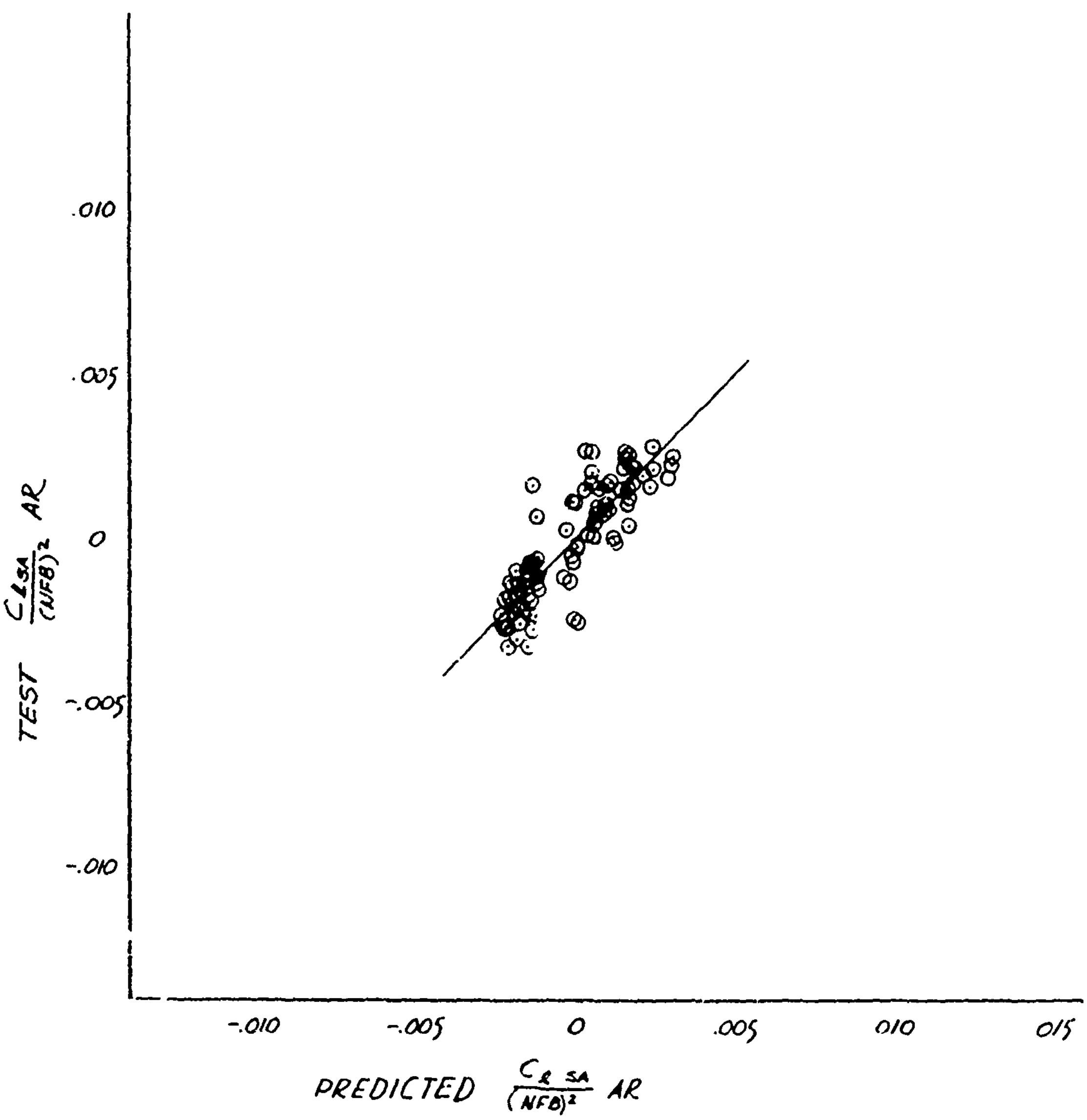
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
ROLLING MOMENT COEFFICIENT

$\alpha_{LOAD} = -9^{\circ}, \ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{\ell_{SA}}}{NFB^2} AR = -.073241 - .000092\ell + .004853D - .000010C + .00000001\text{X} + .0000015 \frac{SA}{FA} \times FSPD + .000213M^2$$



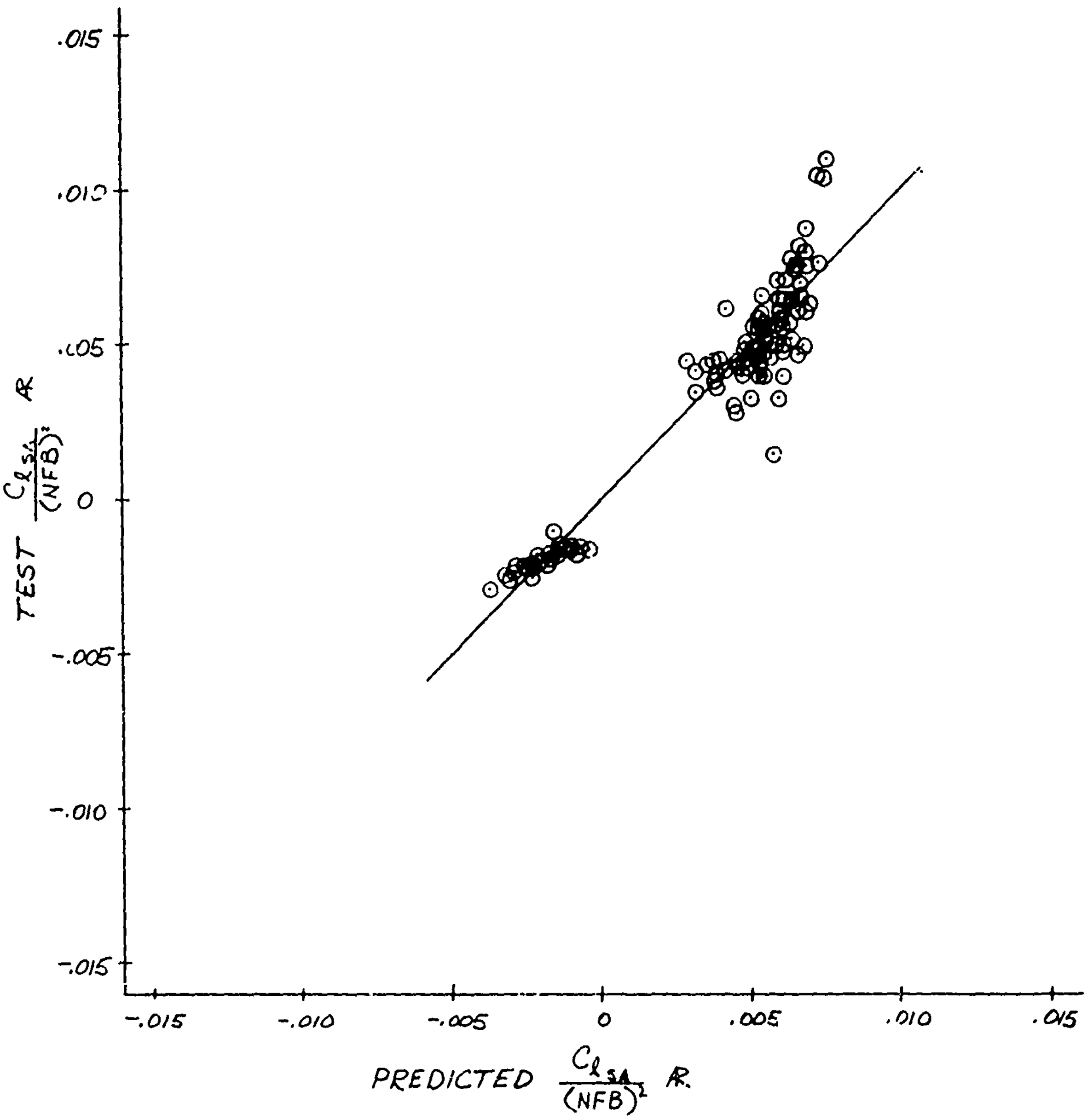
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
ROLLING MOMENT COEFFICIENT

$$\alpha_{LOAD} = 6^{\circ}, \ \beta = +10^{\circ}$$

$$M = .60 - .95$$

$$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$$

$$\frac{C_{\ell_{SA}}}{NFB^2} AR = .039753 - .000087\ell - .001798D + .0000084C + .000063\Delta X - .000003 \frac{SA}{FA} \times FSPD + .002527M^2$$



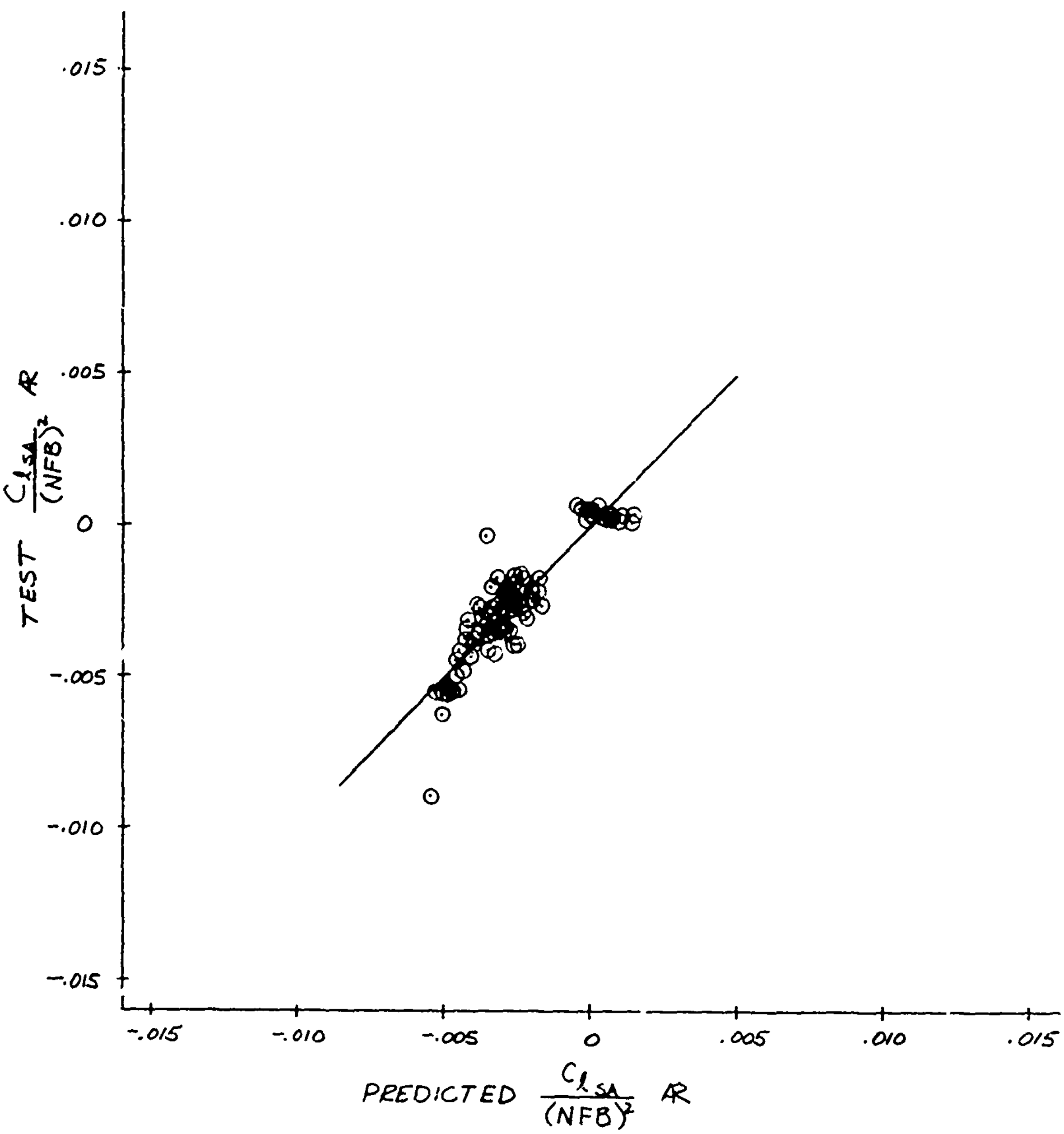
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
Outboard
ROLLING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^\circ,\ \beta = -10^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

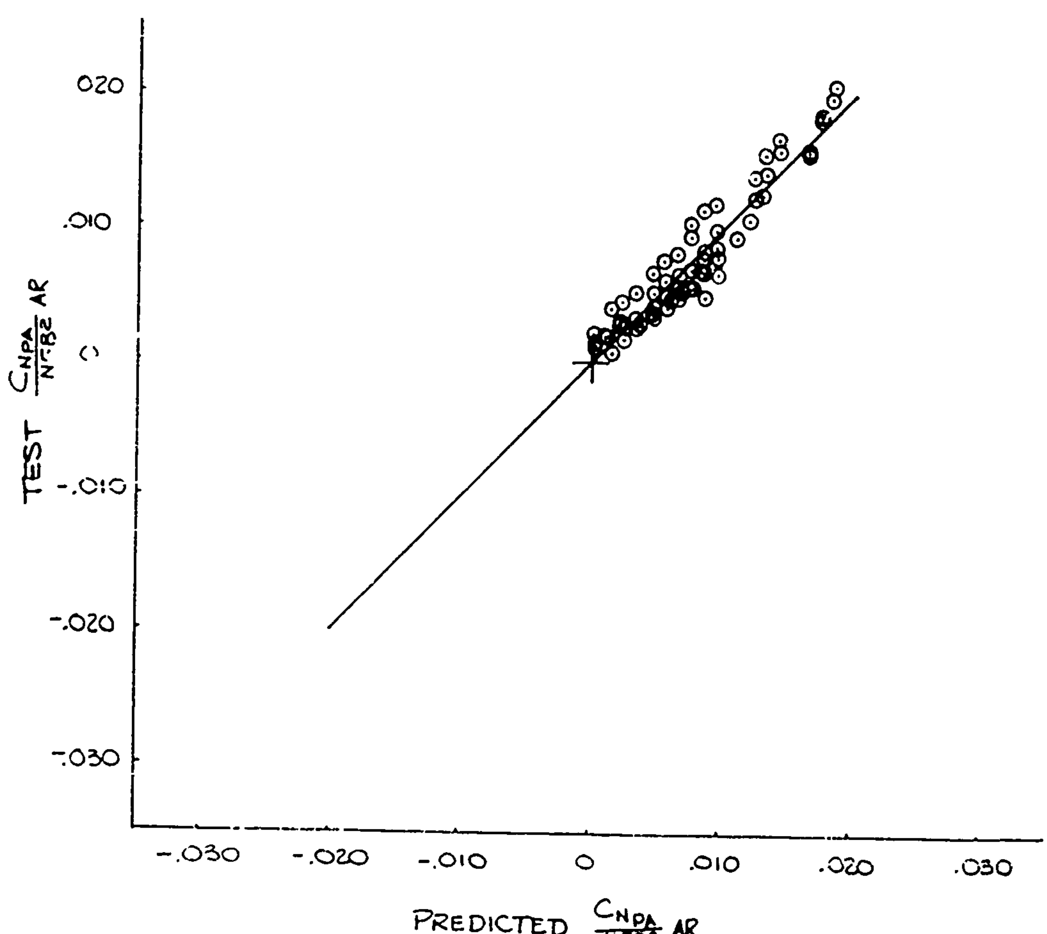
$$\frac{C_{\ell SA}}{NFB^2} AR = -.015173 + .000022\ell + .000212D + .000055C + .000058\ell X + .0000021\frac{SA}{FA} \times FSPD - .0014899M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK + PYLON
INBOARD
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = 16^\circ \quad \beta = 0^\circ$
$M = .6- \ .95$
$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{N_{pA}}}{NFB^2} AR = .0046345 + .0002472\ell - .0029391D - .0002361C$$
$$-.0001882\Delta X + .0000022 \frac{PA}{FA} FSPD - .0034984M^2$$



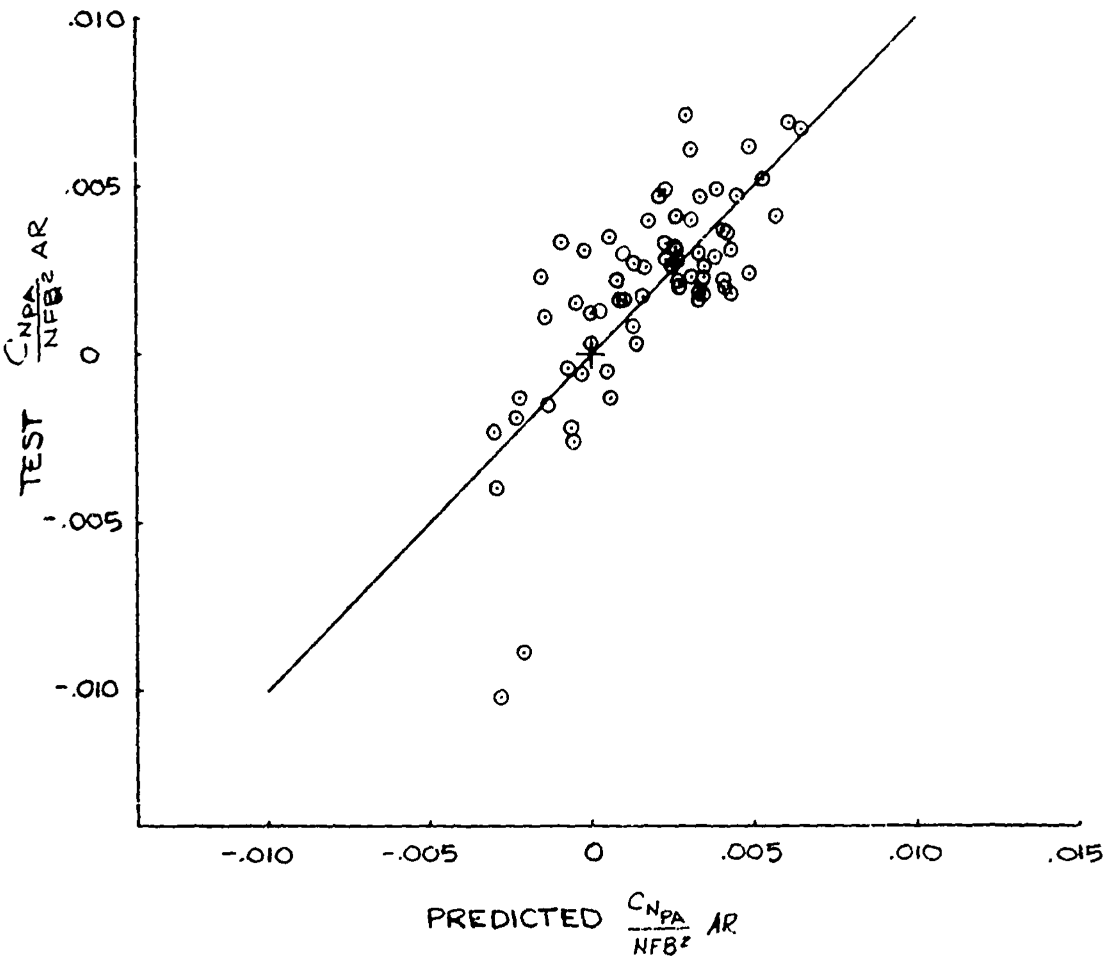
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK + PYLON
INBOARD
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \quad \beta = 0^{\circ}$

$M = .6 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

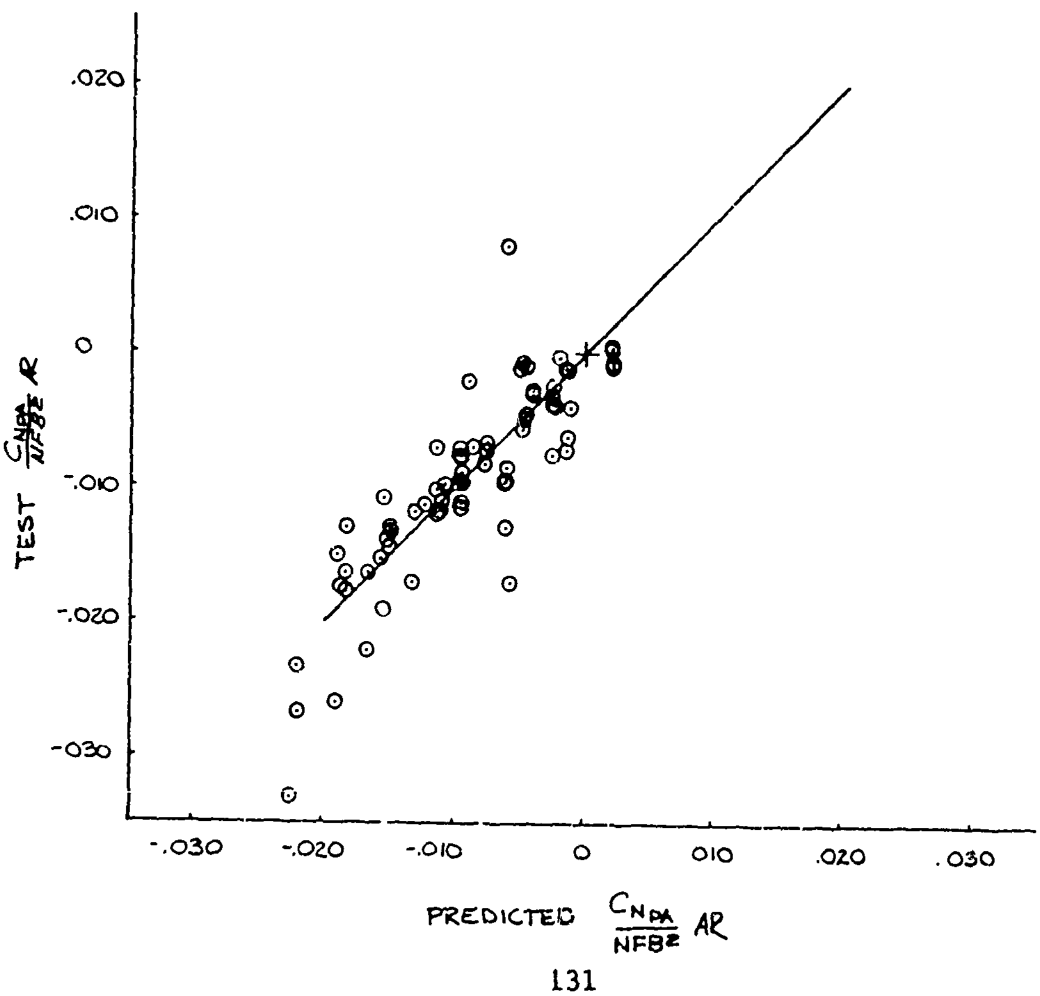
$$\frac{C_{NPA}}{NFB^2} AR = .0392677 + .0001926\ell - .0035766D + .0000643C$$
$$-.0001789\Delta X + .0000075 \frac{PA}{FA} FSPD - .0027803M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK + PYLON
INBOARD
NORMAL FORCE COEFFICIENT

α LOAD = -4°, β = 0°
M = .6 - .95
Λ LE = 16° - 72.5°

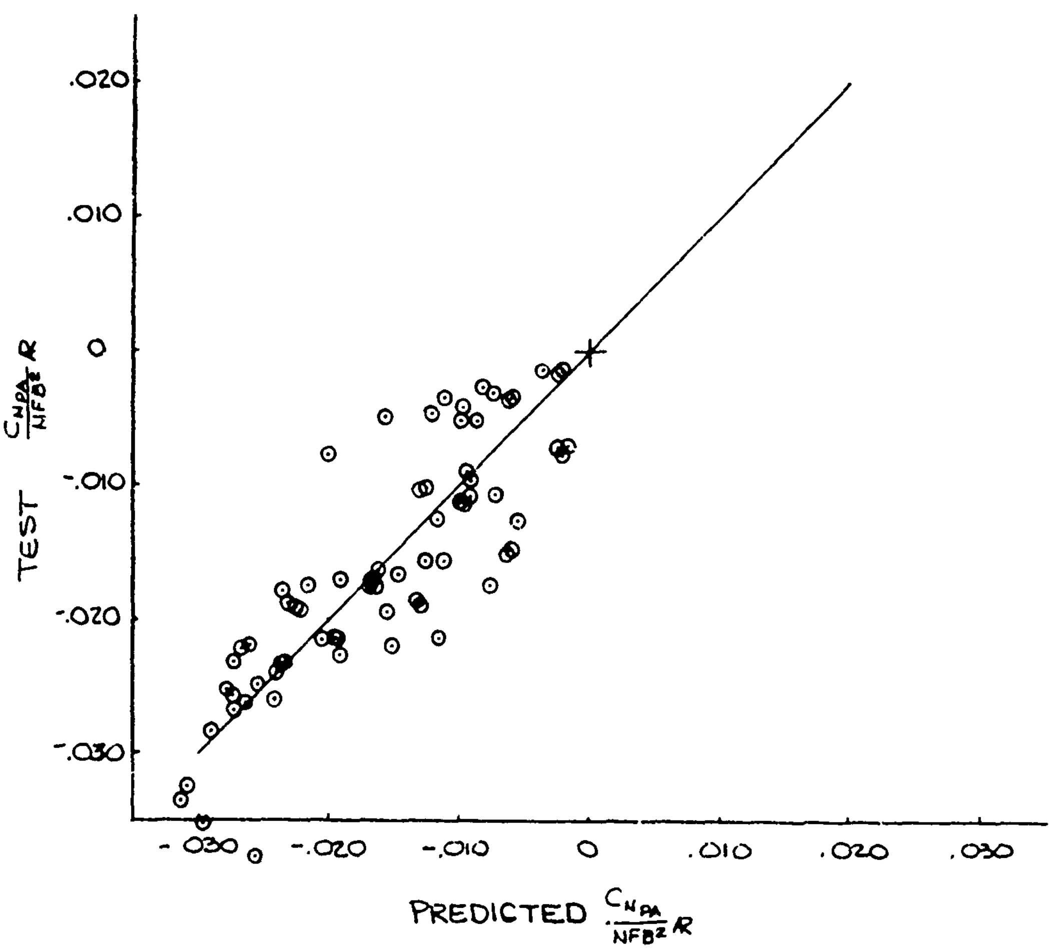
$$\frac{C_{NPA}}{NFB^2} AR = .3080345 + .0006389\ell - .0216784D - .0000069C$$
$$-.0002547\Delta X - .0000025\frac{PA}{FA} \ FSPD - .0129680M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK + PYLON
INBOARD
NORMAL FORCE COEFFICIENT

α LOAD = -9°, $\beta = 0^{\circ}$
M = .6 - .95
$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

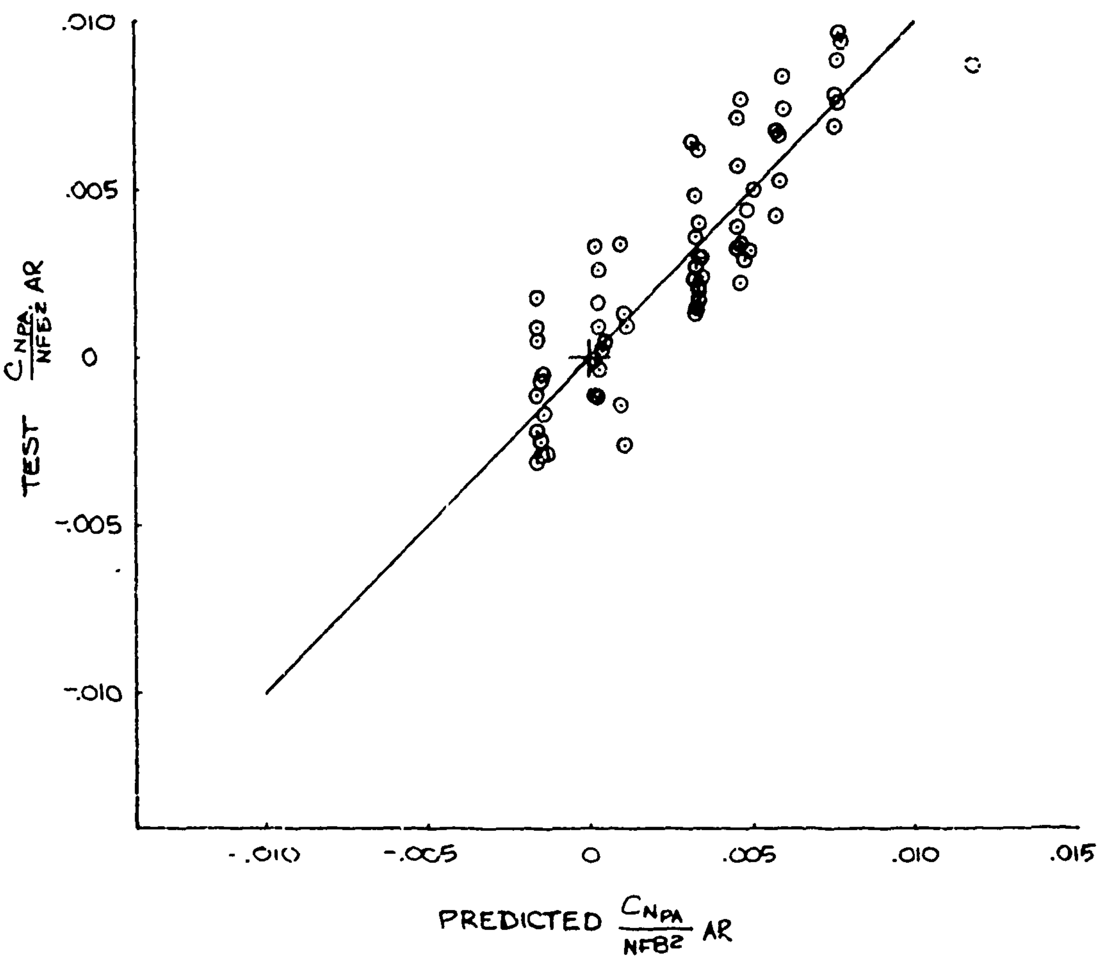
$$\frac{C_{NPA}}{NFB^2} AR = .4241661 + .0009421\alpha - .0286388D - .0002069C - .0004086\Delta X - .0000141 \frac{PA}{FA} FSPD - .0137638M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK + PYLON
INBOARD
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = 6^\circ,\ \beta = +10^\circ$
$M = .6 - .95$
$\Lambda_{LE} = 16^\circ - 72.5^\circ$

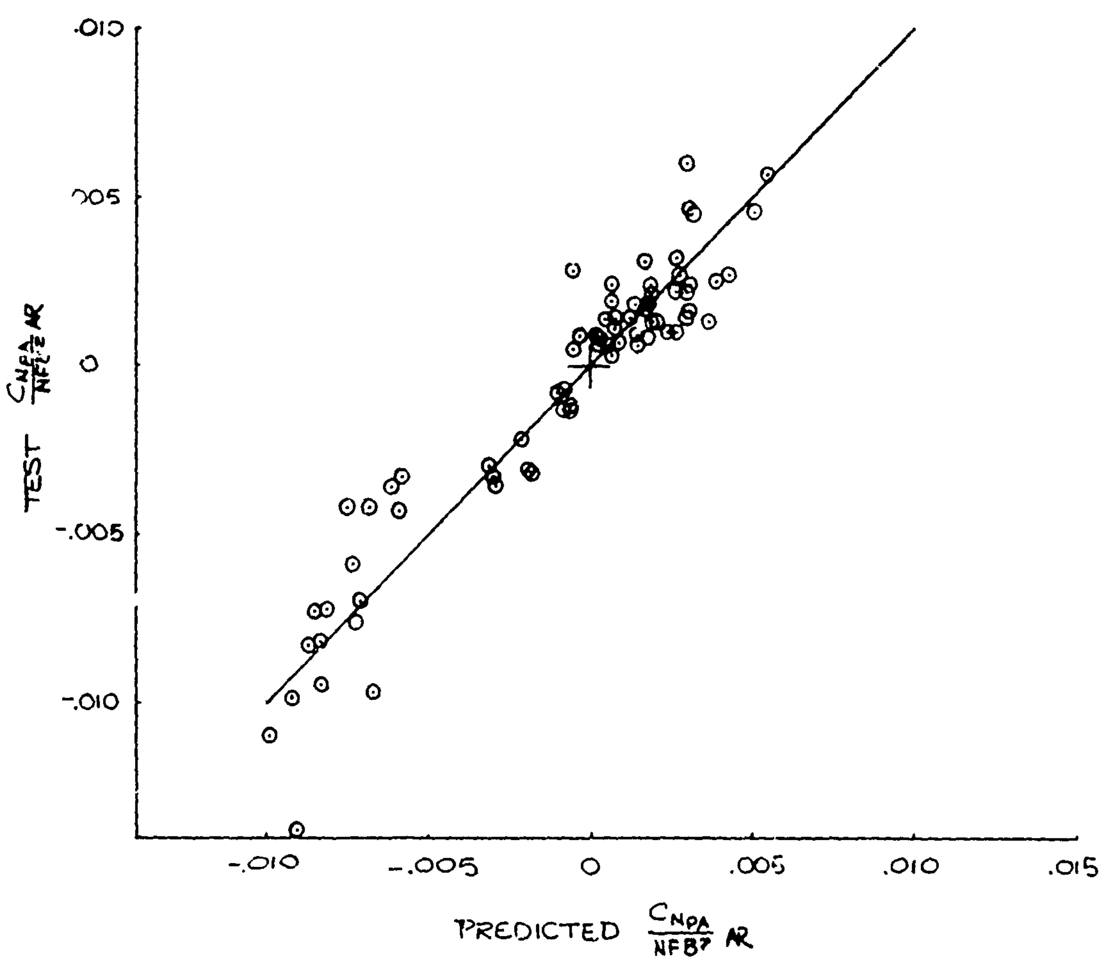
$$\frac{C_{N_{PA}}}{NFB^2}\ AR = .0728322 + .0002660\ell - .0046136D - .0001246C$$
$$-.0001776\Delta X + .0000005\ \frac{PA}{FA}\ FSPD - .0002743M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK + PYLON
INBOARD
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = 6^\circ, \quad \beta = -10^\circ$
$M = .6 - .95$
$\Lambda_{LE} = 16^\circ - 72.5^\circ$

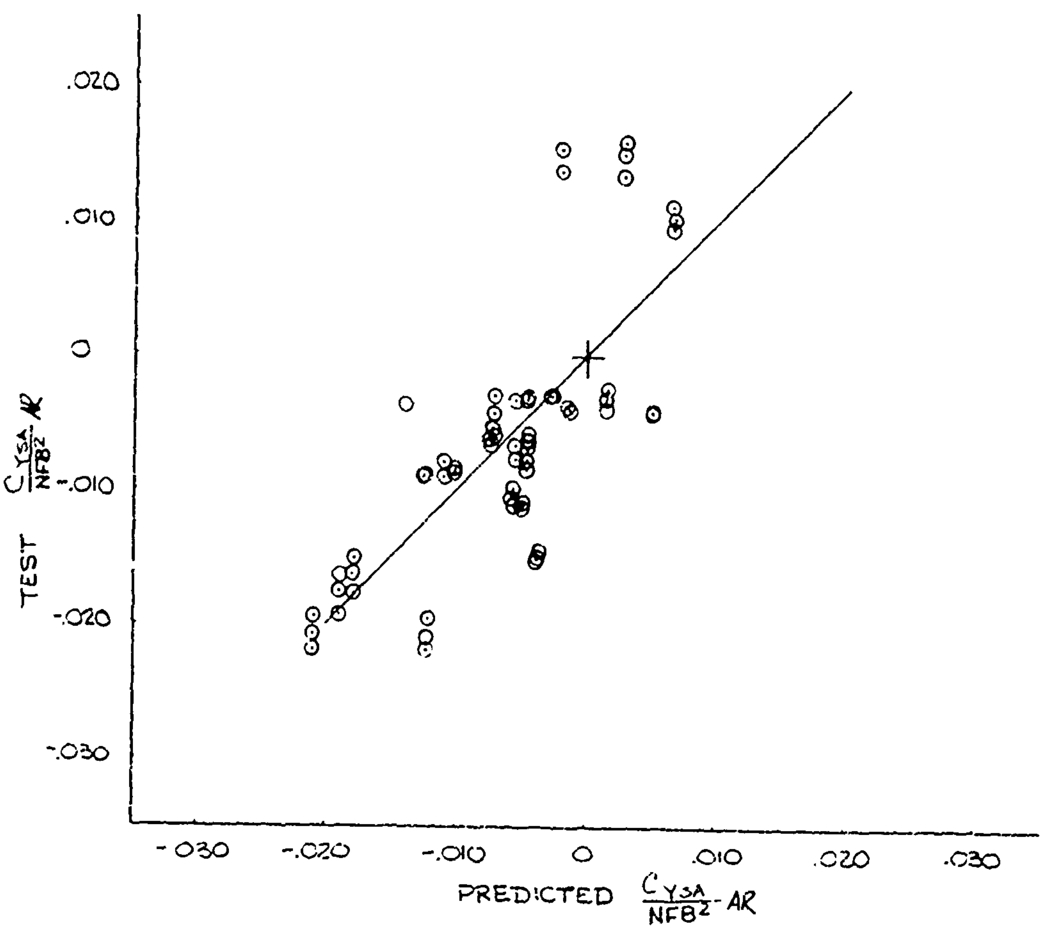
$$\frac{C_{N_P}A}{NFB^2} AR = .1637947 + .0004322\ell - .0120925D + .0000239C$$
$$-.0001831\Delta X + .0000070 \frac{PA}{PA} \times FSPD - .0044355M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK + PYLON
INBOARD
SLIDE FORCE COEFFICIENT

α LOAD = 16°, β = 0°
M = .6 - .95
Λ_{LE} = 16° - 72.5°

$$\frac{C_{YSA}}{NFB^2}\ AR = .0077993 + .0001094\ell - .0038968D + .0002840C$$
$$-.0004038\Delta X + .0000463\ \frac{SA}{FA} \times FSPD - .0001347M^2$$

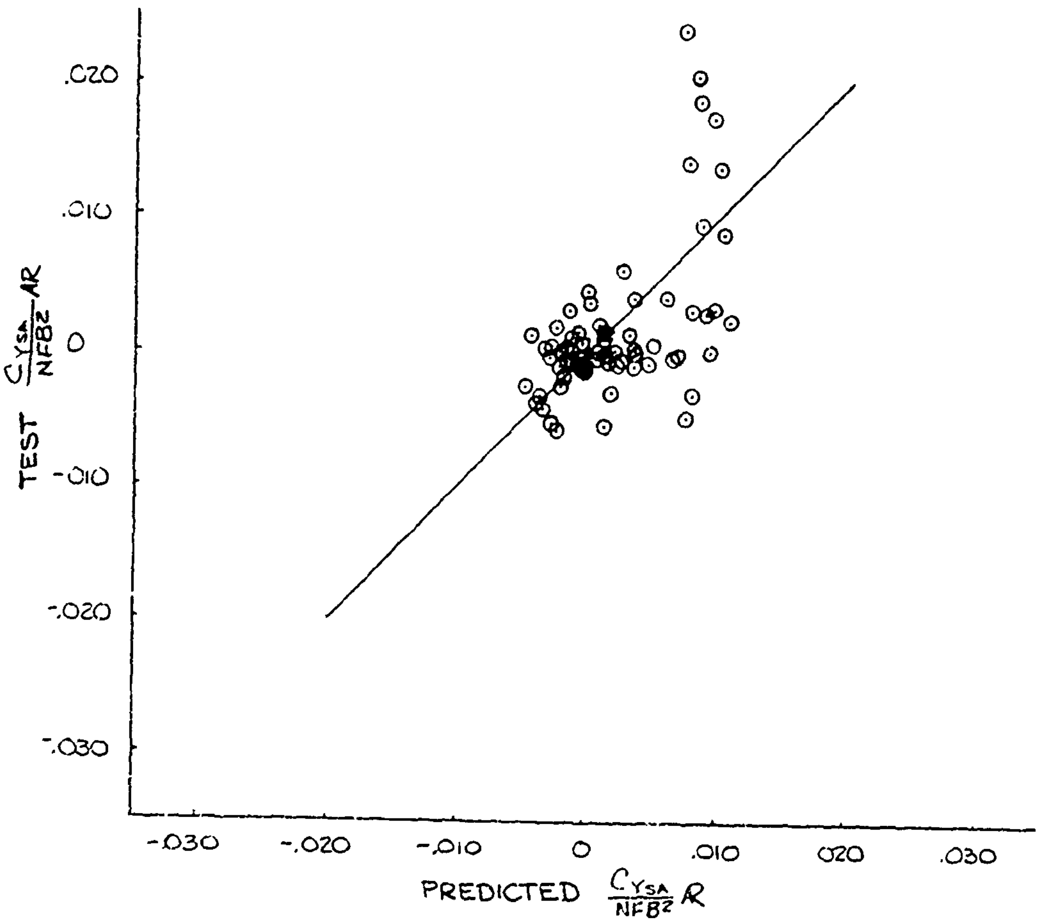


COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK + PYLON
INBOARD
SLIDE FORCE COEFFICIENT

$\alpha_{LOAD} = 6^\circ, \quad \beta = 0^\circ$
$M = .6 - .95$
$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{YSA}}{NFB^2} AR = -.0611542 - .0008066\ell + .0038506D + .0000197[illegible]$$

$$-.0001310\Delta X + .0000191 \frac{SA}{FA} \times FSPD - .0038372M^2$$

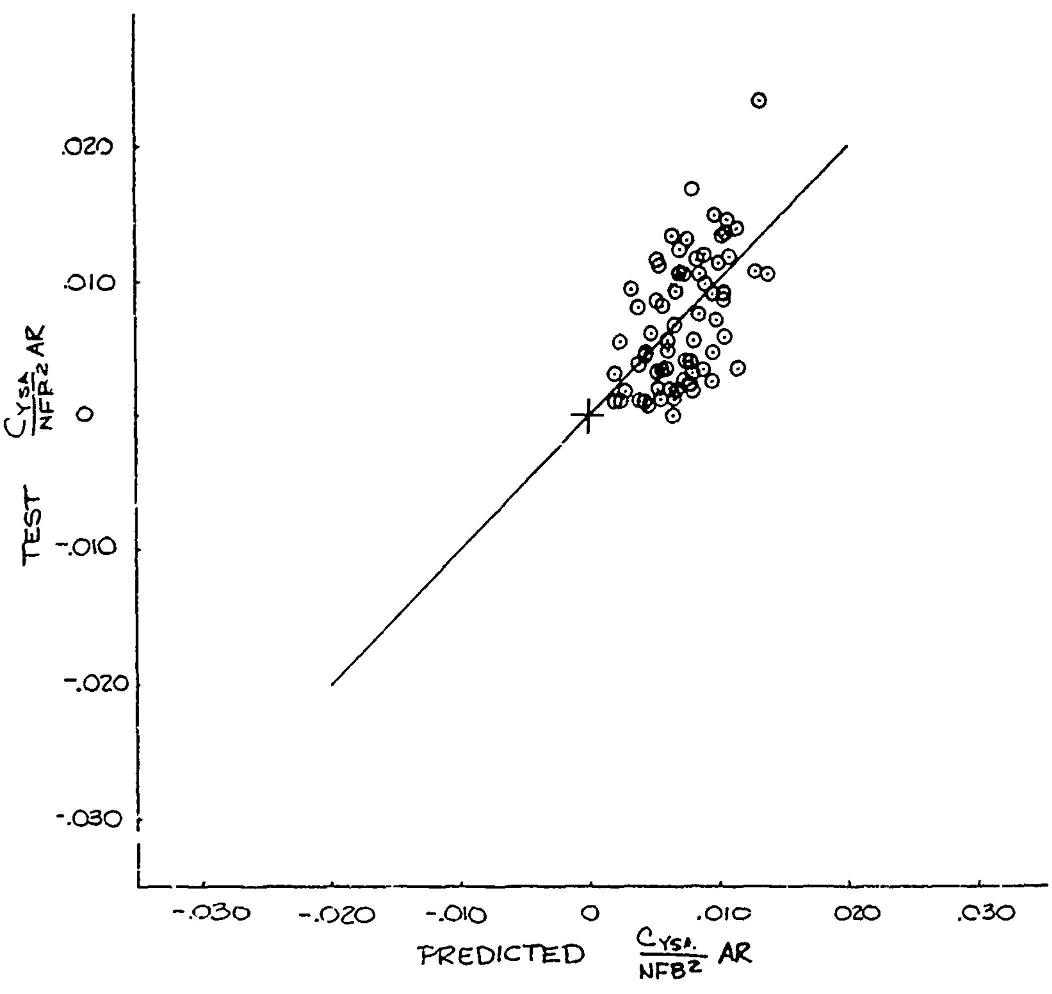


COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK + PYLON
INBOARD
SIDE FORCE COEFFICIENT

α LOAD = -4°, $\beta = 0^{\circ}$
M = .6 - .95
$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{YSA}}{NFB^2} AR = -.0193436 - .0001554\ell + .0052563D - .0003555C$$

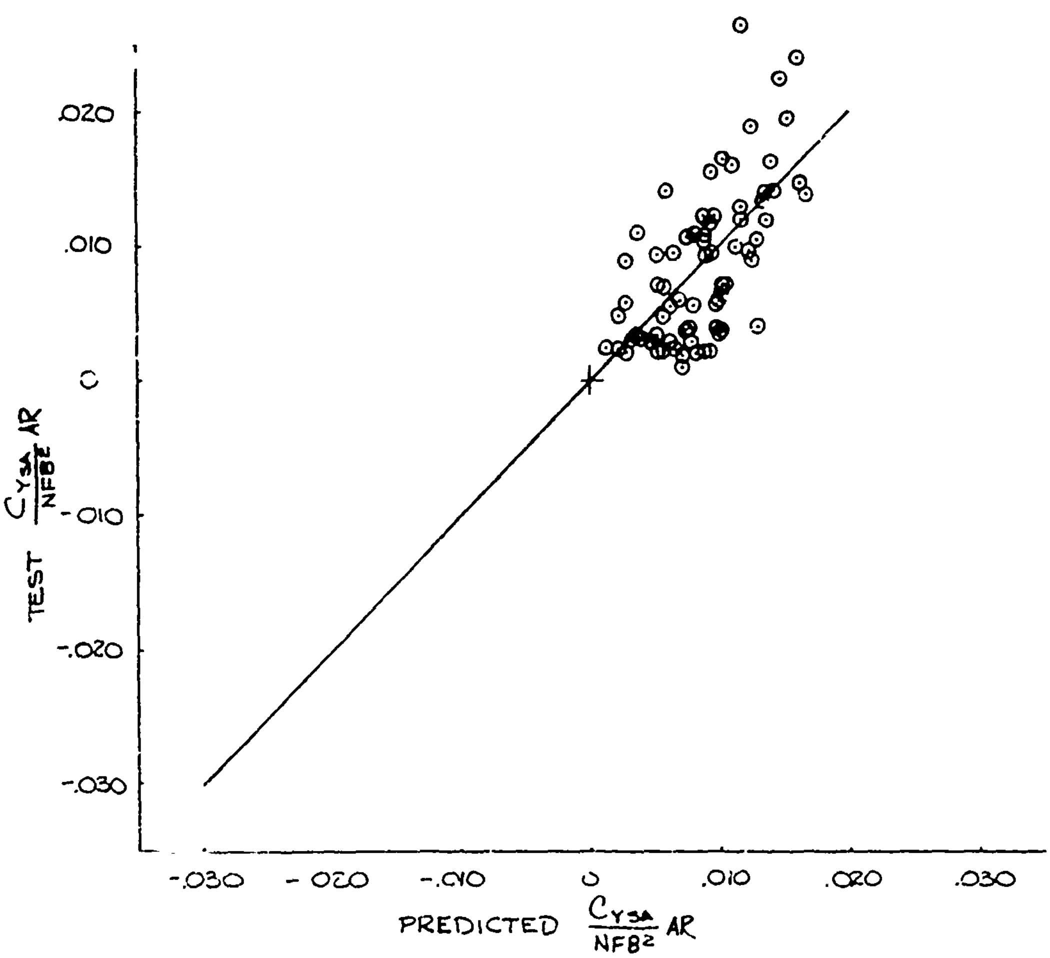
$$+.0001220\Delta X - .0000227 \frac{SA}{FA} \times FSPD - .0066710M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK + PYLON
INBOARD
SIDE FORCE COEFFICIENT

α LOAD = -9°, β = 0°
M = .6 - .95
Λ_{LE} = 16° -72.5°

$$\frac{C_{YSA}}{NFB^2} AR = -.0580801 - .0002145\ell + .0080027D - .0003445C + .0001221\Delta X - .0000241\frac{SA}{FA} \times FSPD - .0102425M^2$$

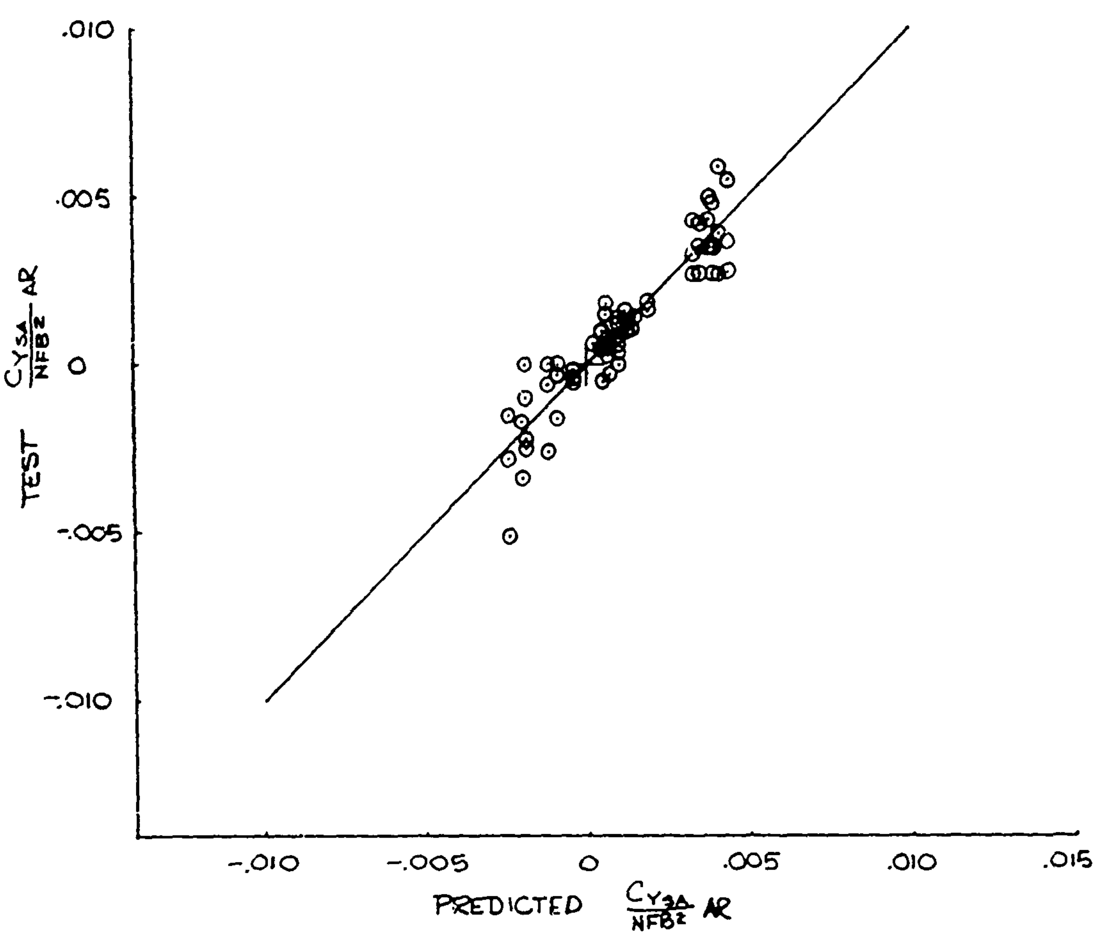


COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK + PYLON
INBOARD
SIDE FORCE COEFFICIENT

α LOAD = 6°, β = +10°
M = .6 - .95
Λ_{LE} = 16° - 72.5°

$$\frac{C_{Y_{SA}}}{NFB^2} AR = .0000360 - .0000806\ell + .0019274D - .0001780C$$

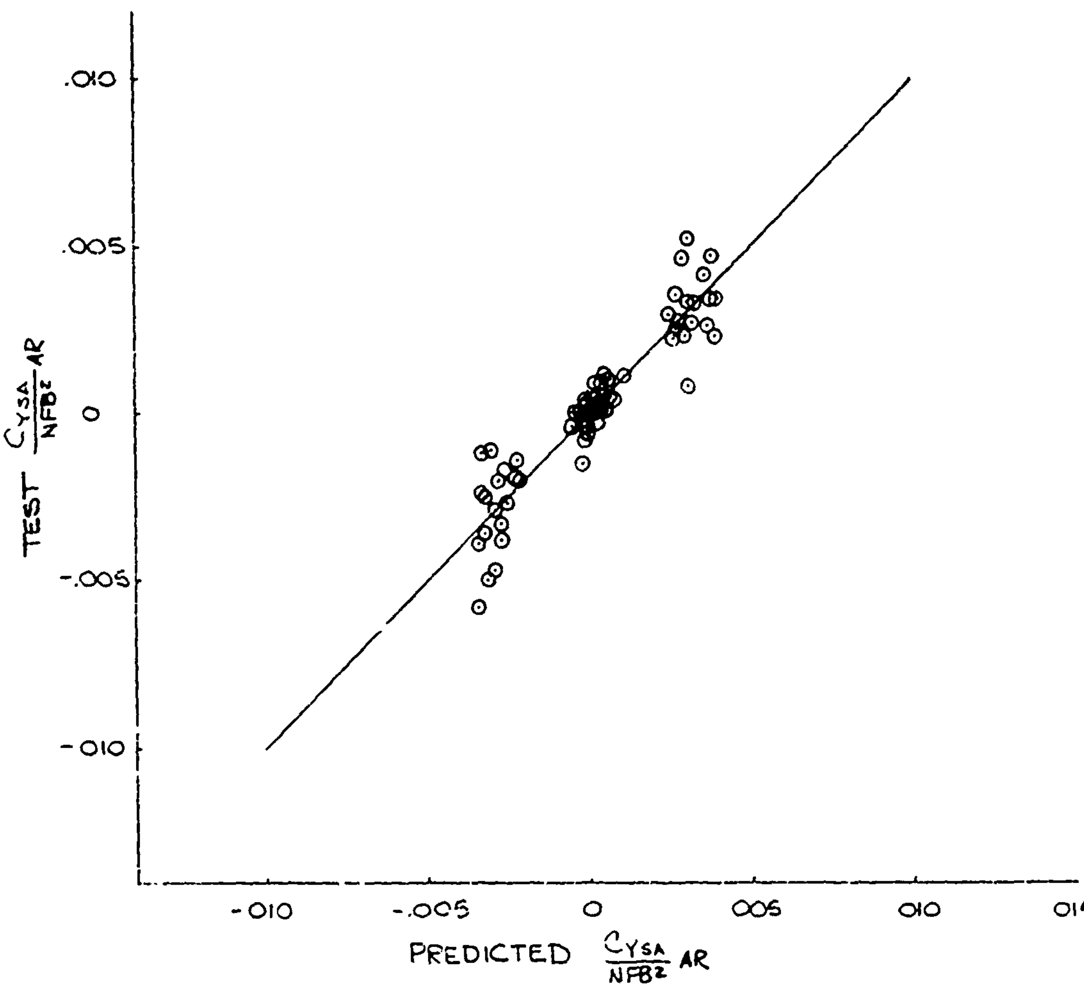
$$-.0000055\Delta X - .0000115\frac{SA}{FA} \times FSPD + .0000134M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK + PYLON
INBOARD
SIDE FORCE COEFFICIENT

α LOAD = 6°, β = -10°
M = .6 - .95
Λ_{LE} = 16° - .72.5°

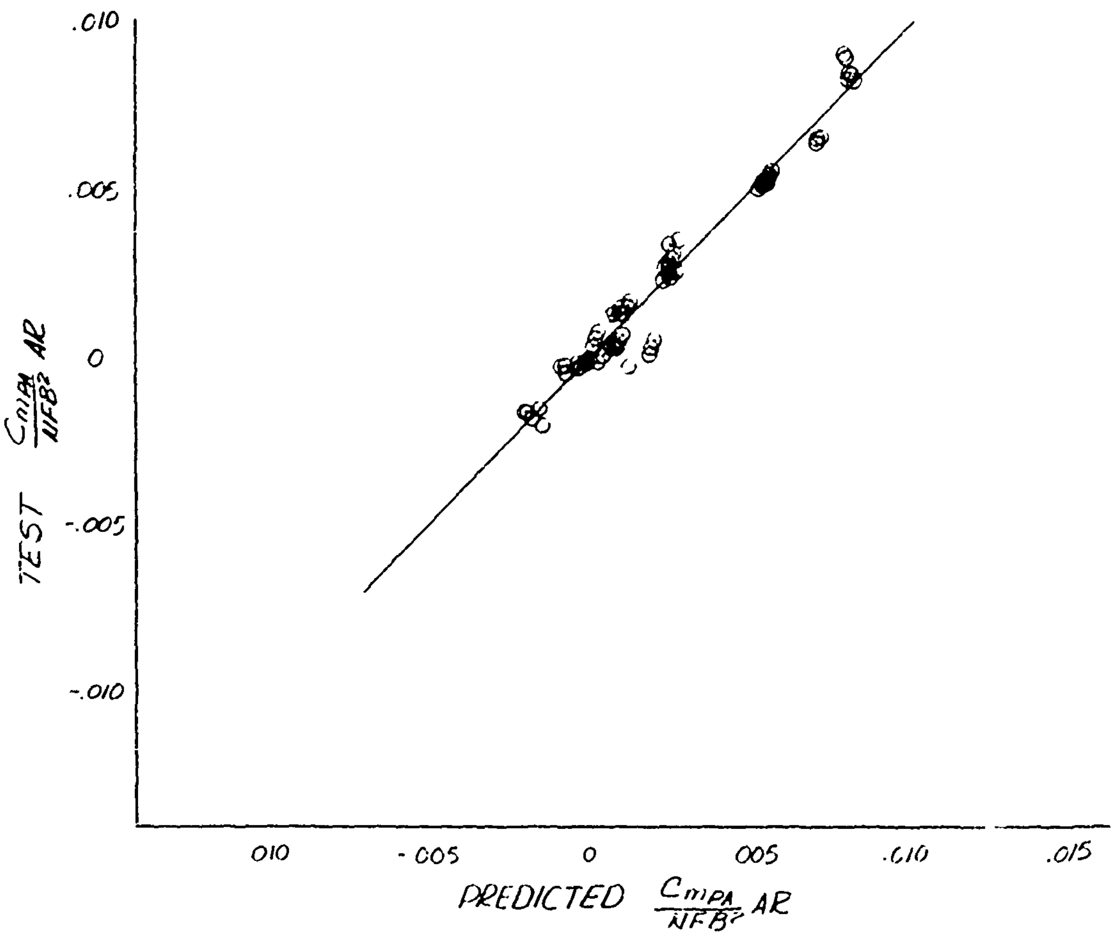
$$\frac{C_{Y_{SA}}}{NFB^2} AR = -.0012219 - .0000780\ell + .0017490D - .0001560C$$
$$- .0000287\Delta X - .0000088\,\frac{SA}{FA} \times FSPD + .0002753M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK + PYLON
INBOARD
PITCHING MOMENT COEFFICIENT

α LOAD = 16°, β = 0°
M = .6 - .95
Λ_{LE} = 16° - 72.5°

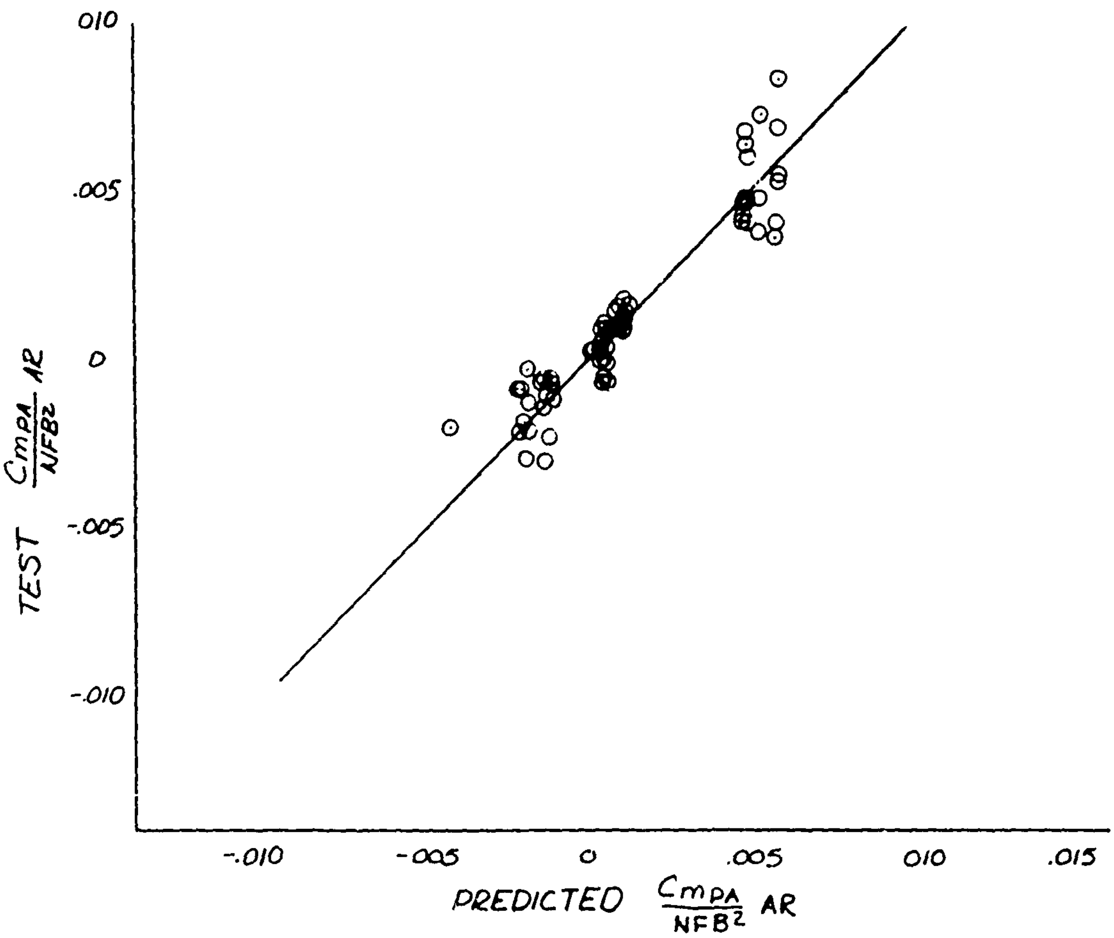
$$\frac{C_{M_{PA}}}{NFB^2} AR = - .0563884 - .0001997\ell + .0053897D - .0001095C + .0000653\Delta X - .0000069 \frac{PA}{FA} \times FSPD - .0003341M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK + PYLON
INBOARD
PITCHING MOMENT COEFFICIENT

α LOAD = 6°, β = 0°
M = .6 - .95
Λ_{LE} = 16° - 72.5°

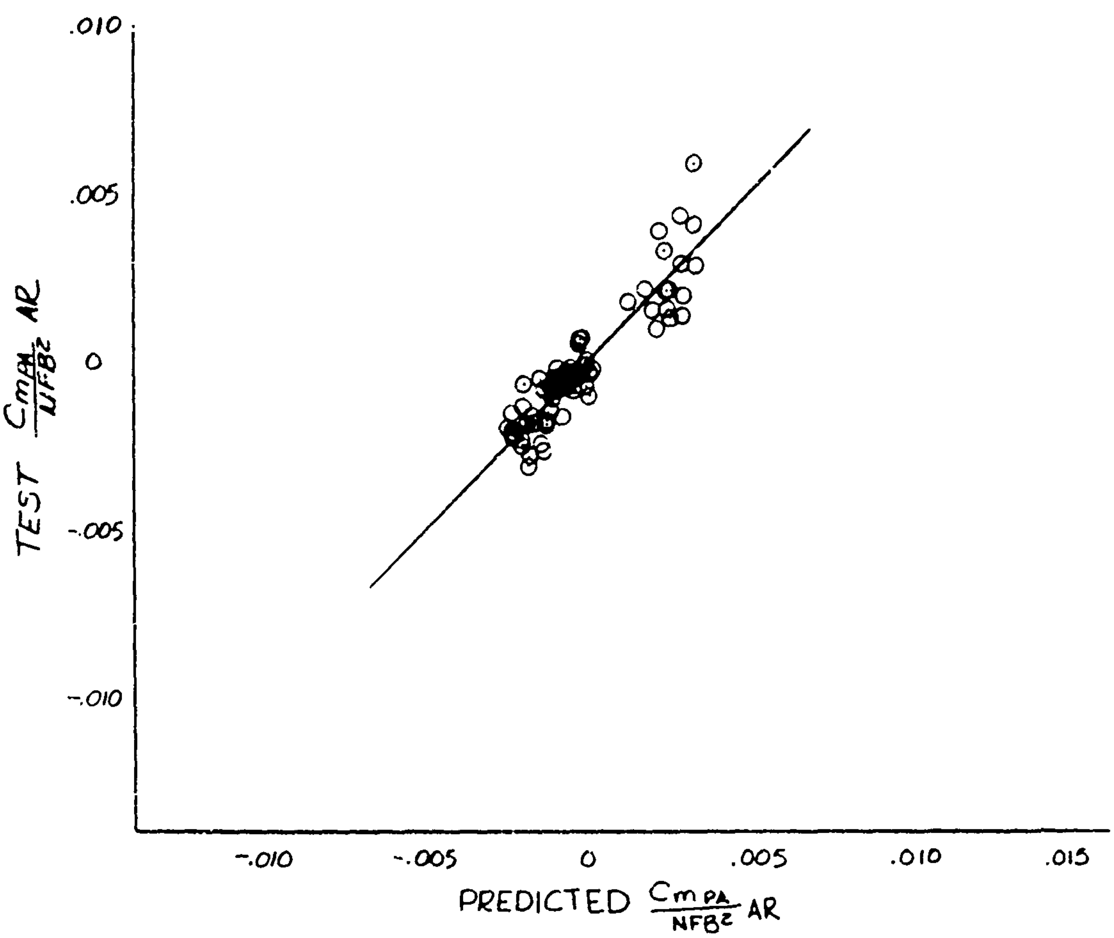
$$\frac{C_{MPA}}{NFB^2} AR = -.0639977 - .0001750\ell + .0052407D - .0000540C - .0000042\Delta X - .0000029 \frac{PA}{FA} \times FSPD + .00020157M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK + PYLON
INBOARD
PITCHING MOMENT COEFFICIENT

$$\alpha_{LOAD} = -4^\circ, \quad \beta = 0^\circ$$
$$M = .6 - .95$$
$$\Lambda_{LE} = 16^\circ - 72.5^\circ$$

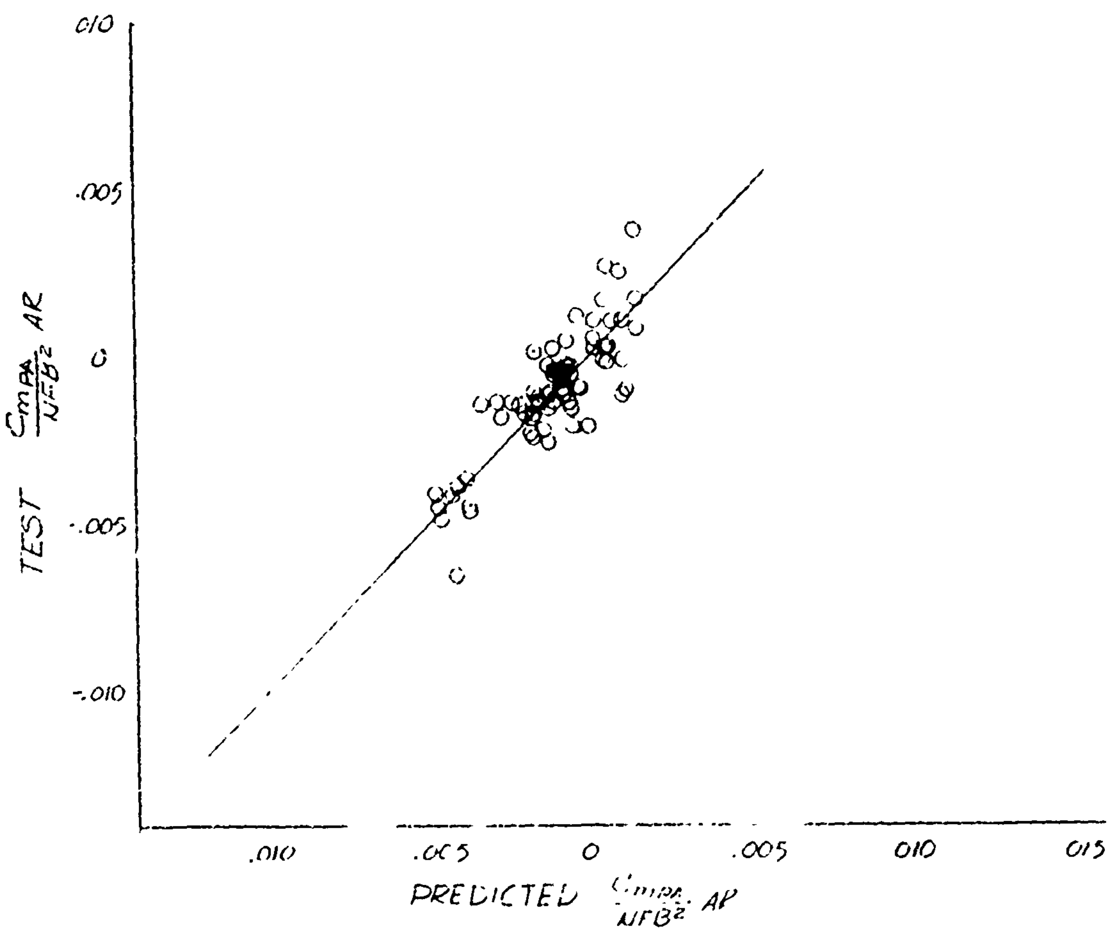
$$\frac{C_{M_{P_A}}}{NFB^2} AR = -.0776852 - .0000914\ell + .0052603D - .0000208C$$
$$-.0001423\Delta X + .0000020 \frac{PA}{FA} \times FSPD + .0016659M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK + PYLON
INBOARD
PITCHING MOMENT COEFFICIENT

$\alpha = -9^{\circ}, \quad \beta = 0^{\circ}$
$M = .6 - .95$
$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

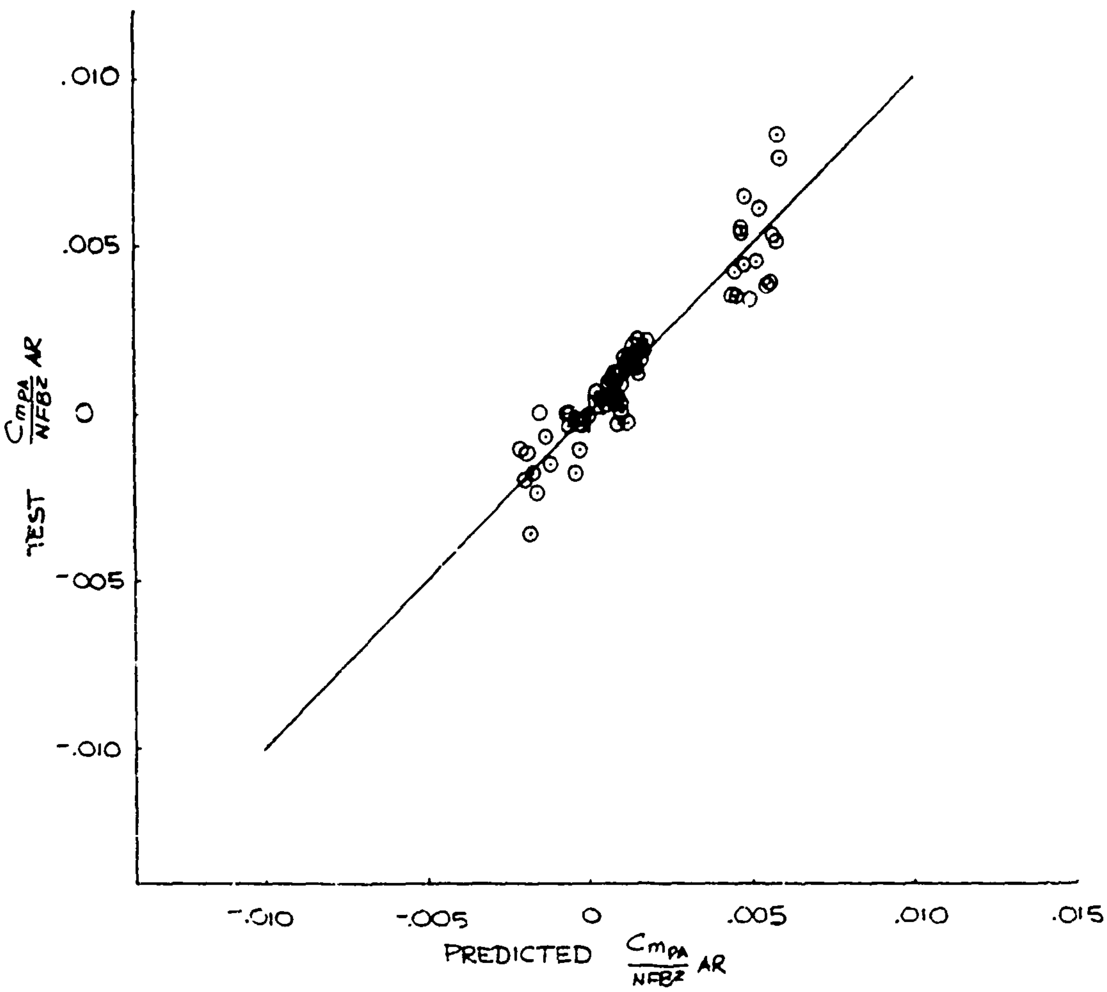
$$\frac{C_{MPA}}{NFB^2} AR = -.0779592 - .0000023\ell + .0050193D - .0000515C - .0002559\Delta X + .0000029 \frac{PA}{FA} \times FSPD + .0017576M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK + PYLON
INBOARD
PITCHING MOMENT COEFFICIENT

$$\alpha = 6^\circ, \qquad \beta = +10^\circ$$
$$M = .6 - .95$$
$$\Lambda_{LE} = 16^\circ - 72.5^\circ$$

$$\frac{C_{M_{PA}}}{NFB^2}\ AR = -\ .0525438 - .0001500\ell + .0045336D - .0000675C$$
$$+ .0000078\Delta X - .0000042\ \frac{PA}{FA} \times FSPD + .0005544M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK + PYLON
INBOARD
PITCHING MOMENT COEFFICIENT

$\alpha = 3^\circ, \quad \beta = -10^\circ$
$M = .16 - .95$
$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{M_{PA}}}{NFB^2} AR = -.0487373 - .0001362\ell + .0042187D - .0000698C - .0000192\Delta X - .0000031\frac{PA}{FA} \times FSPD + .0000201M^2$$

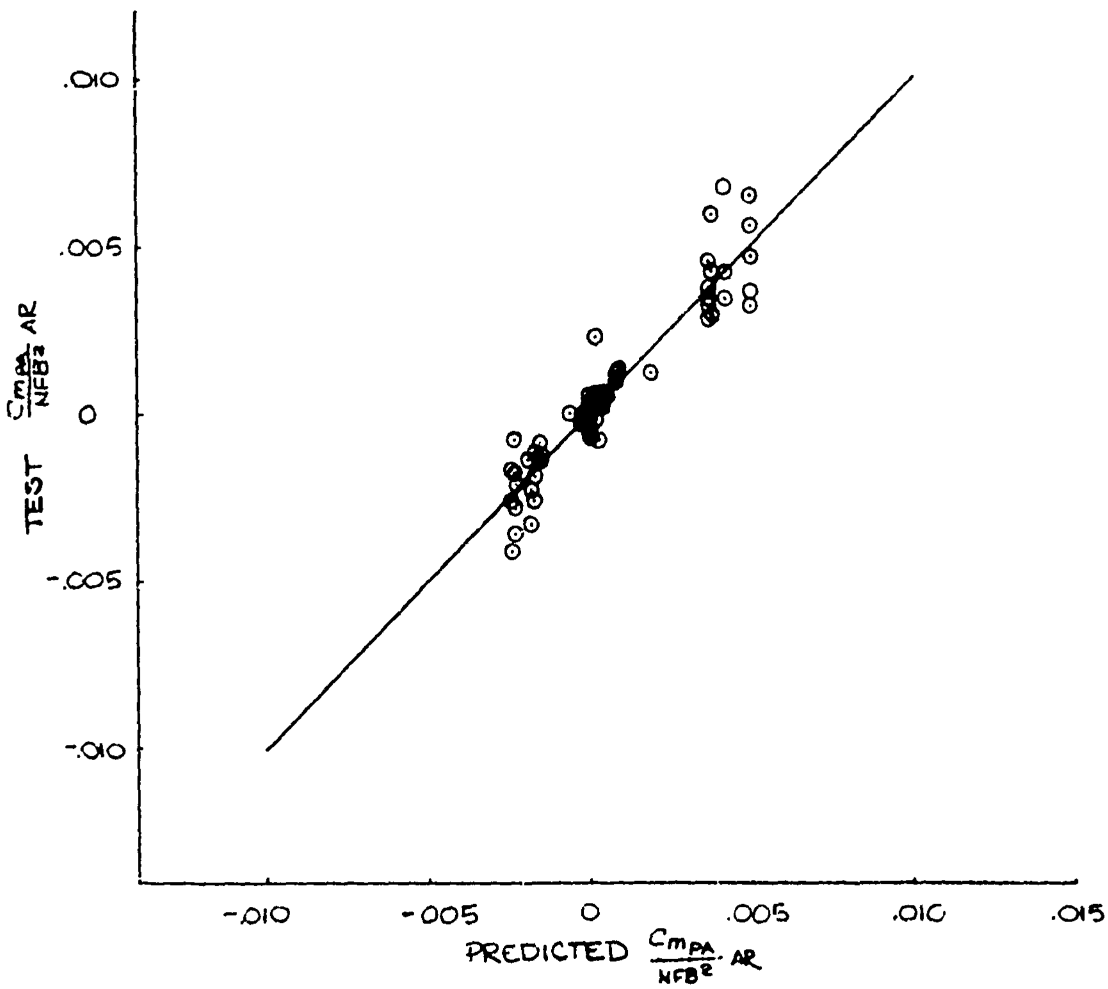
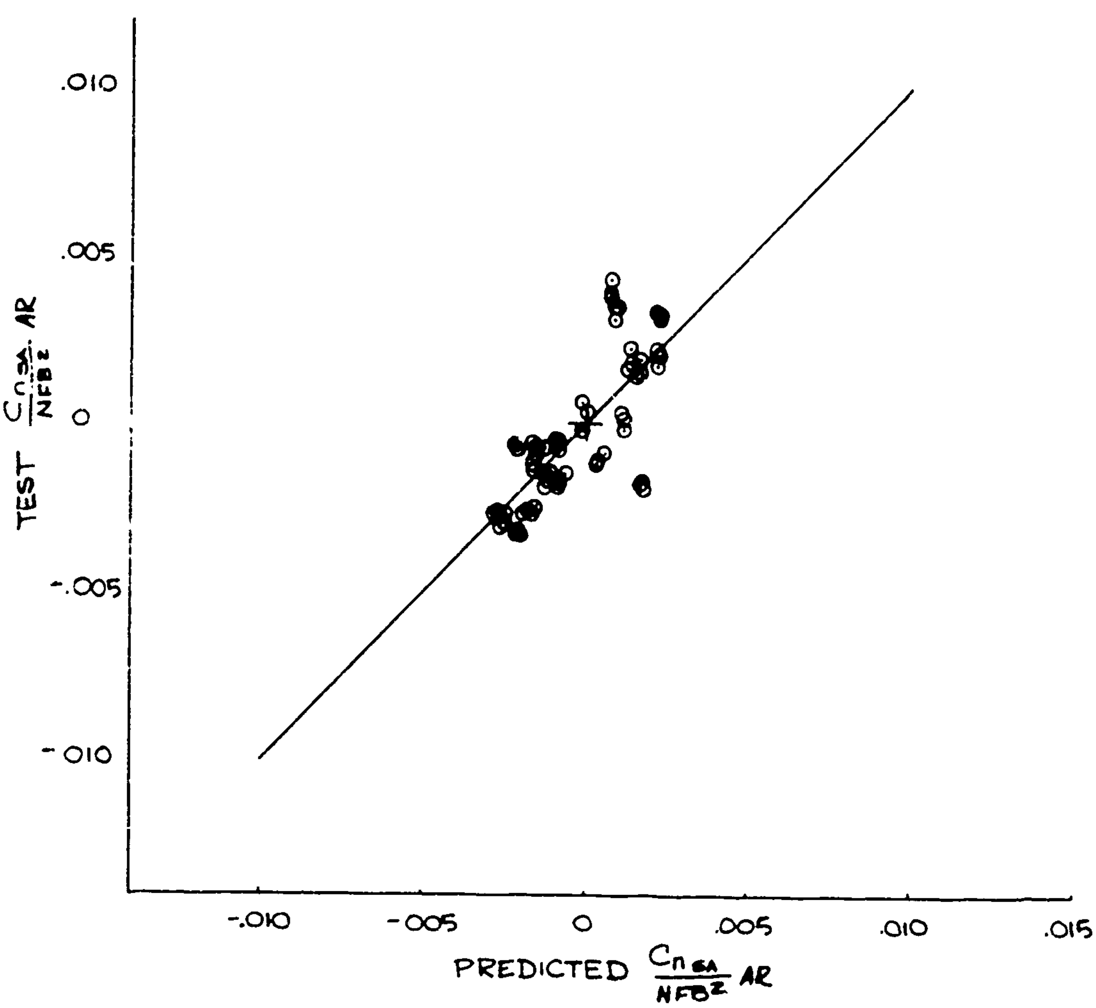


Figure A-48

COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
INBOARD
YAWING MOMENT COEFFICIENT

$\alpha = 16^\circ$, $\beta = 0^\circ$
$M = .6 - .95$, $\Lambda_{LE} = 16^\circ - 72.5^\circ$

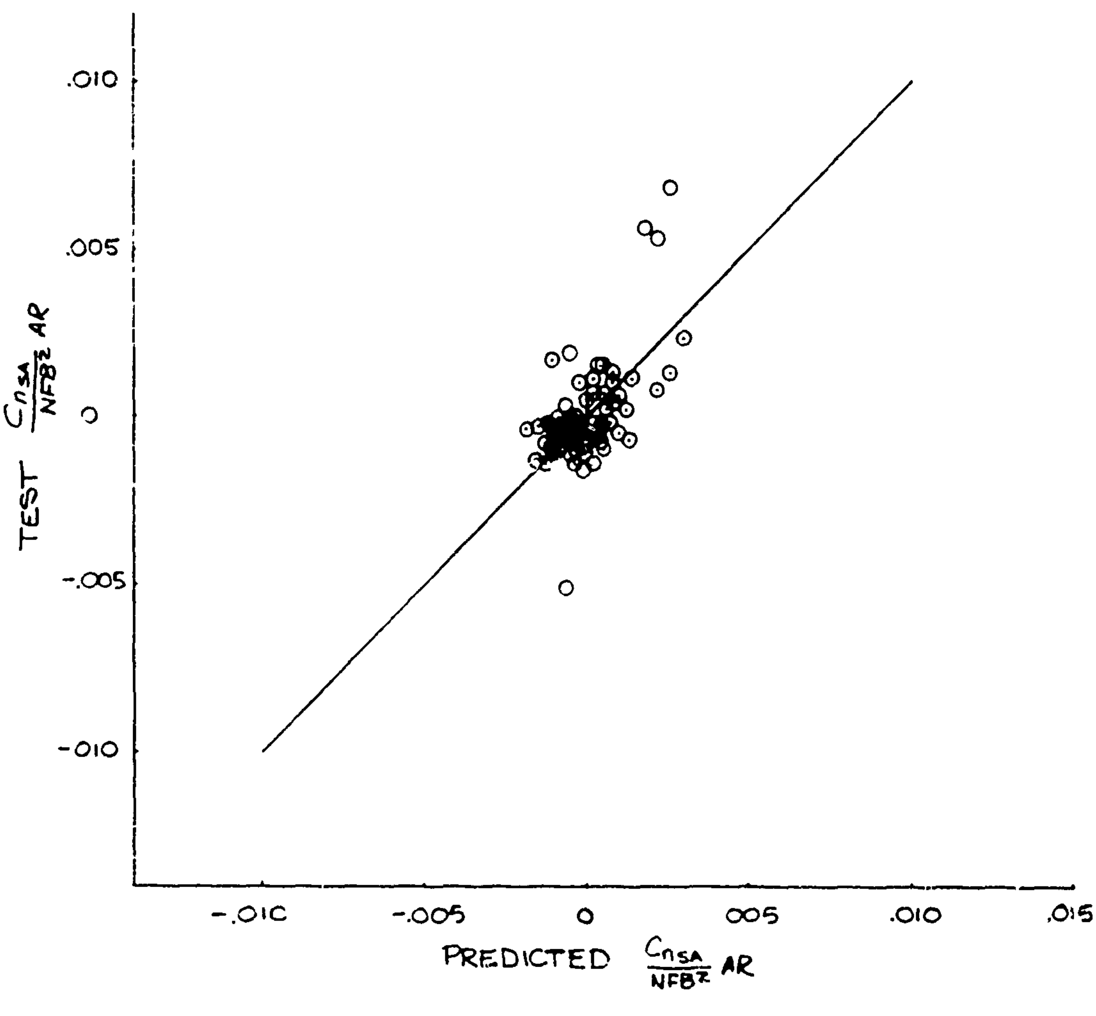
$$\frac{C_{N_{SA}}}{NFB^2} AR = -.0003796 + .0000604\ell + .0018070D - .0002708C$$
$$- .0000927\Delta X - .0000127\frac{SA}{FA} \times FSPD + .0001273M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
INBOARD
YAWING MOMENT COEFFICIENT

$\alpha = +6^\circ, \quad \beta = 0^\circ$
$M = .6 - .95, \quad \Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{NS_A}}{NFB^2} AR = .0183209 + .0000177\ell + .0009493D - .0002743C$$
$$-.0000437\Delta X - .0000144 \frac{SA}{FA} \times FSPD + .0012640M^2$$

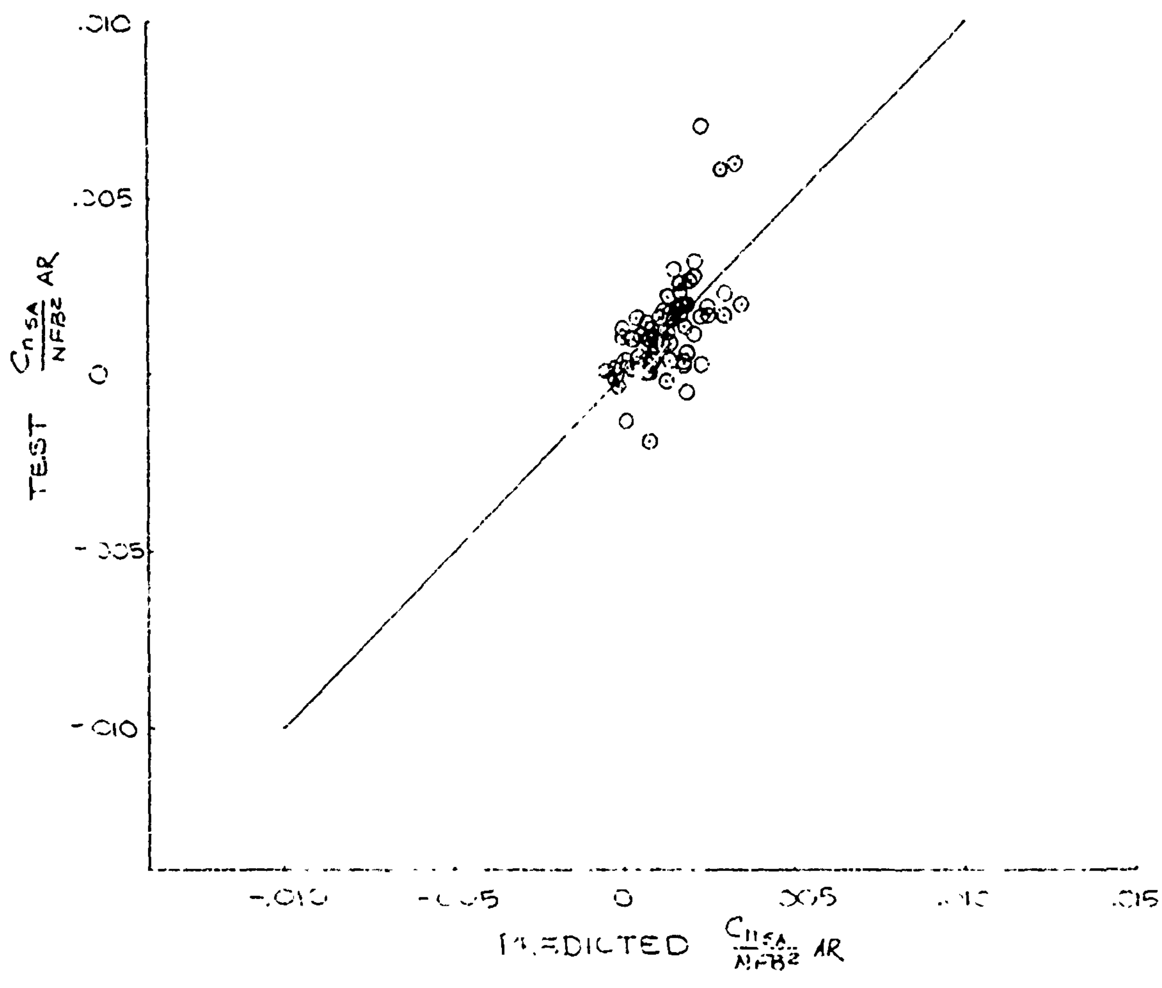


COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
INBOARD
YAWING MOMENT COEFFICIENT

$\alpha = -4^\circ, \quad \beta = 0^\circ$

$M = .6 - .95, \Lambda_{LE} = 16^\circ - 72.5^\circ$

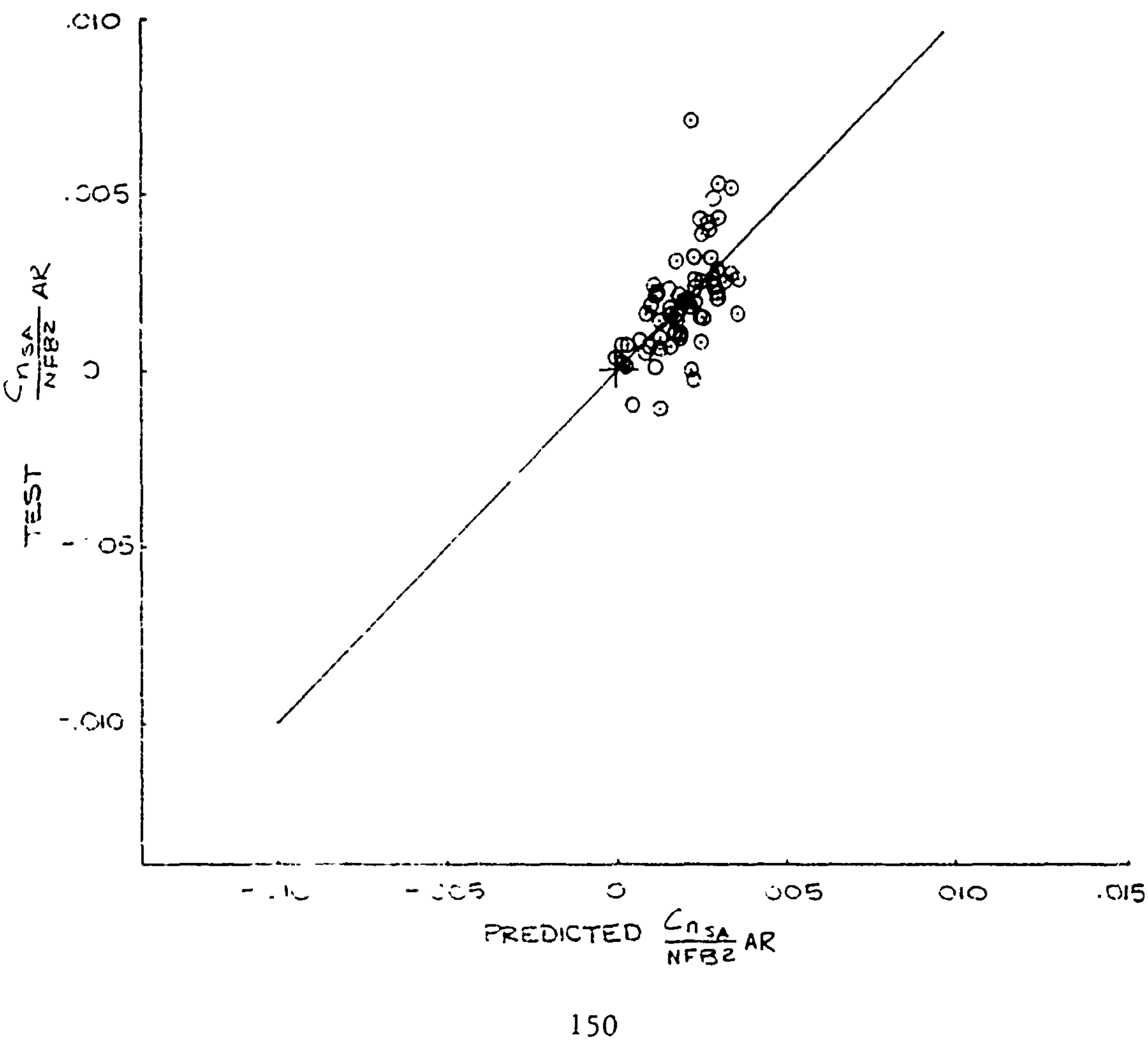
$$\frac{C_{NSA}}{NFB^2} AR = .0041284 - .0000429\ell + .00079250D - .0001042C + .0000530\Delta X - .0000058 \frac{SA}{FA} \times FSPD + .0015949M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
INBOARD
YAWING MOMENT COEFFICIENT

$\alpha = -9^{\circ}$, $\beta = 0^{\circ}$
$M = .6 - .95$, $\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

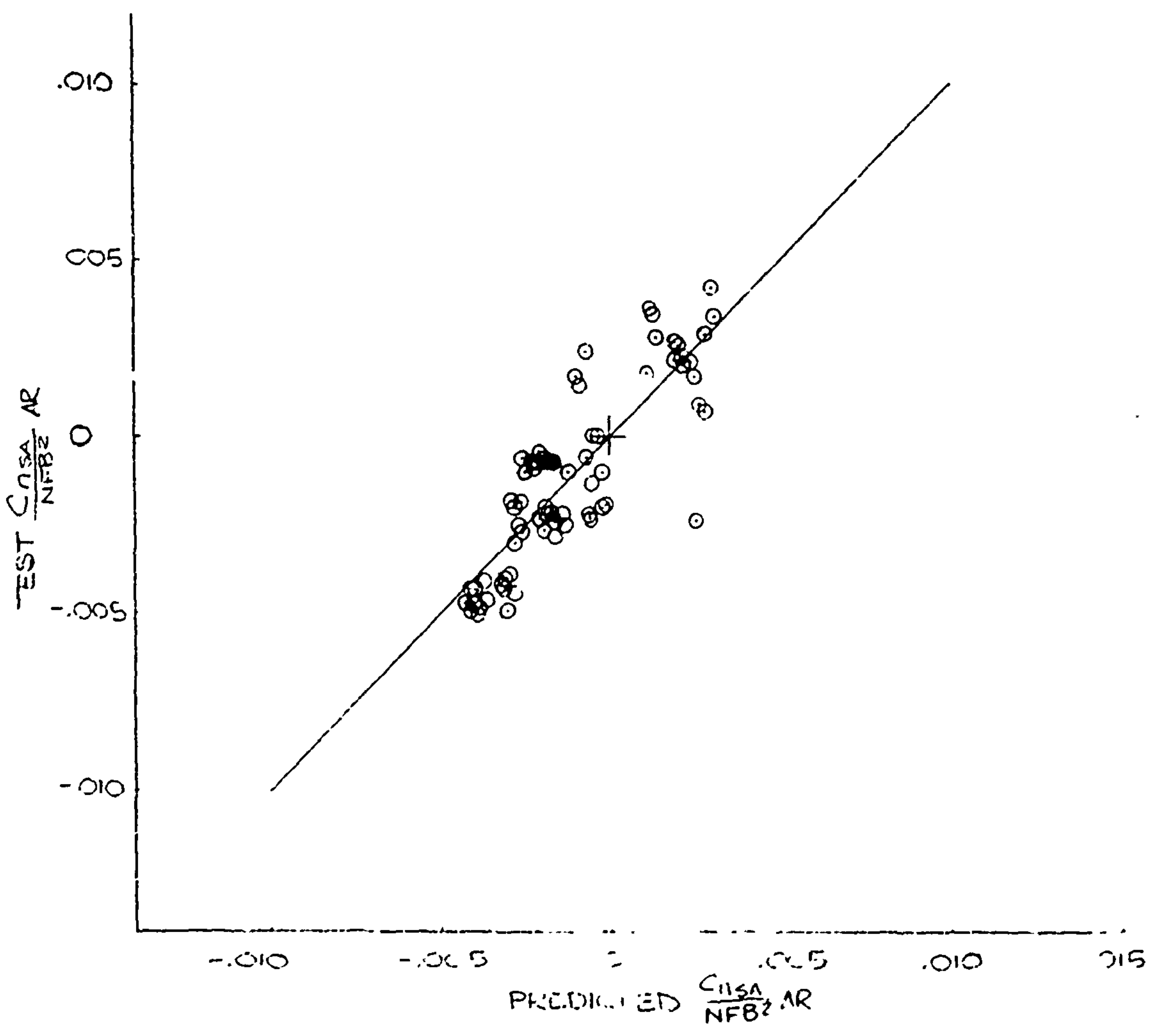
$$\frac{C_{N_{SA}}}{NFB^2} AR = - .0035047 - .0000602\ell + .0010389D - .0000622C$$
$$+ .0000864\Delta X - .0000047 \frac{SA}{FA} \times FSPD + .0019234M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
INBOARD
YAWING MOMENT COEFFICIENT

$\alpha = 6^{\circ}$, $\beta = 10^{\circ}$
$M = .6 - .95$, $\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

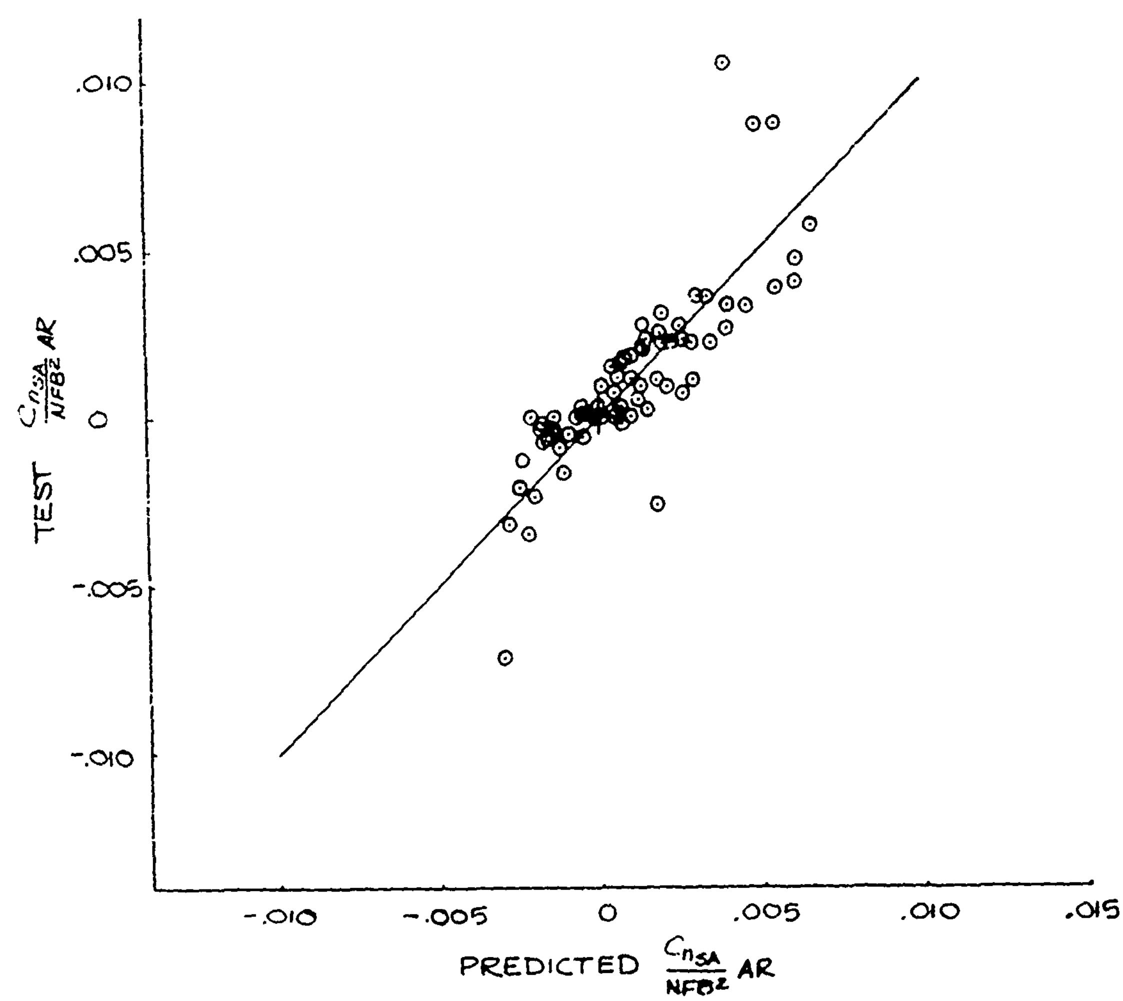
$$\frac{C_{NSA}}{NFB^2} AR = -.0121536 + .0001100\ell + .0018221D - .0002204C - .0001544\Delta X - .0000082 \frac{SA}{FA} \times FSPD + .0004205M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
INBOARD
YAWING MOMENT COEFFICIENT

$\alpha = 6^{\circ}, \quad \beta = -10^{\circ}$
$M = .6 - .95, \Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

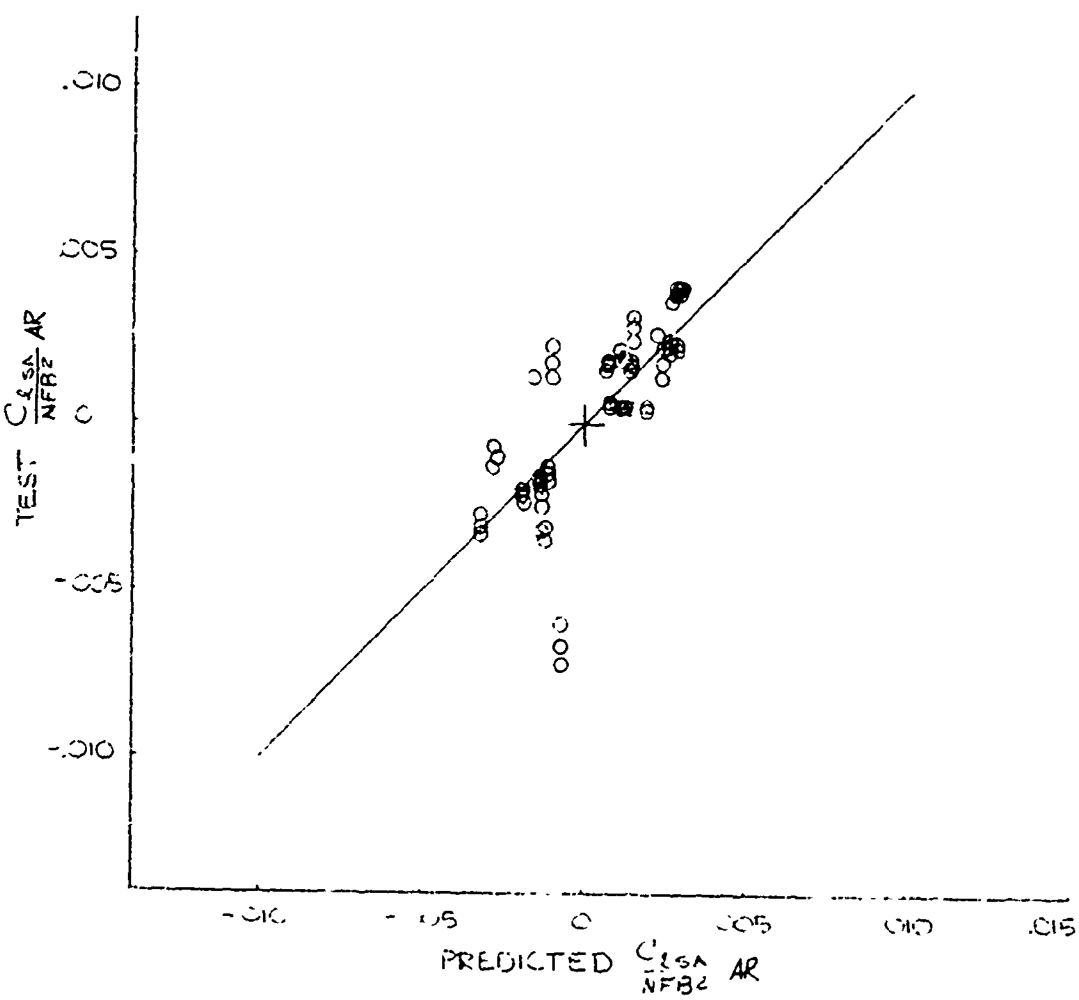
$$\frac{C_{N_{SA}}}{NFB^2} AR = .0305137 - .0000651\ell + .0012609D - .0003436C + .0000065\Delta X - .0000200 \frac{SA}{FA} \times FSPD + .00171114M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
INBOARD
ROLLING MOMENT COEFFICIENT

$\alpha = 16^\circ$, $\beta = 0^\circ$
M = .6 - .95, = $16^\circ - 72.5^\circ$

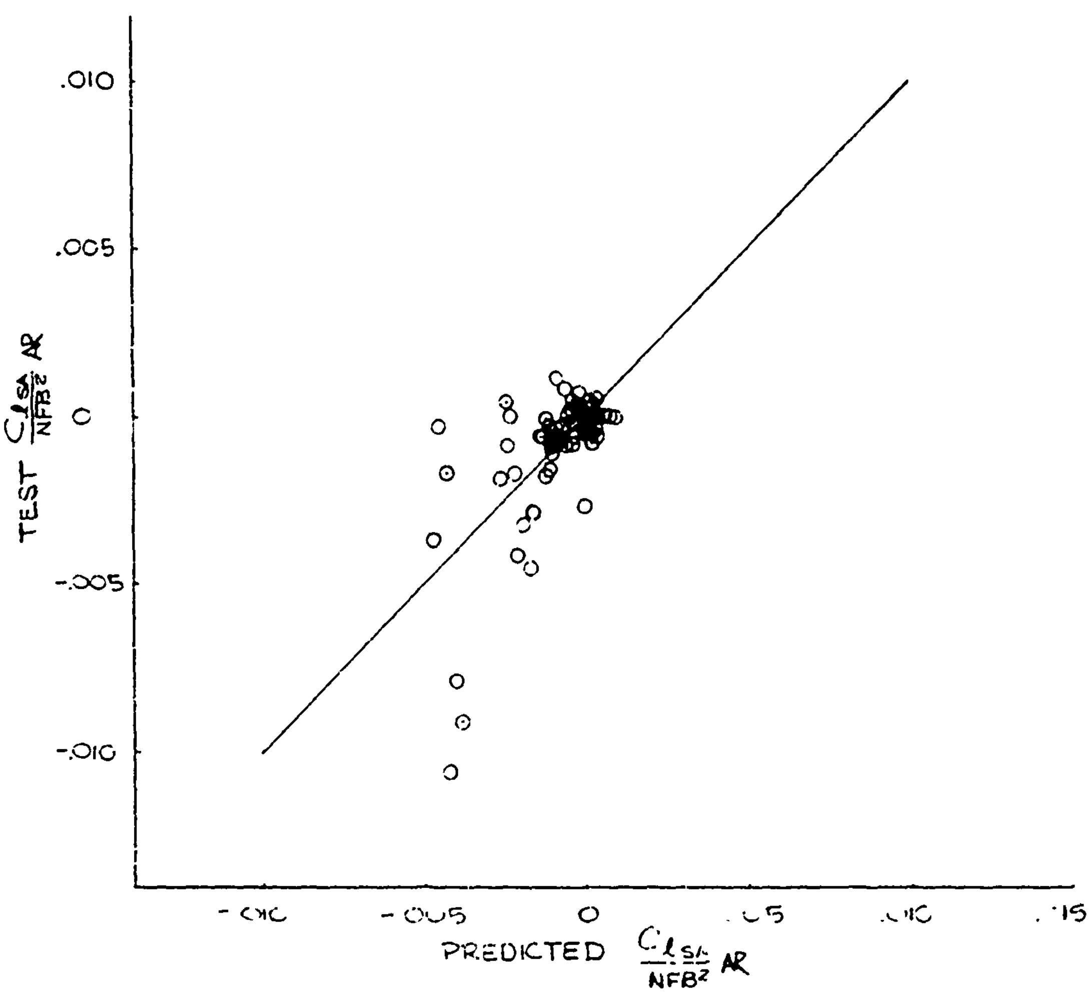
$$\frac{C_{\ell SA}}{NFB^2} AR = - .0298824 - .0001161\ell + .0002465D + .0002800C$$
$$+ .0000992\Delta X + .0000113 \frac{SA}{FA} \times FSPD + .0000446M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
INBOARD
ROLLING MOMENT COEFFICIENT

$\alpha = 6^\circ$, $\beta = 0^\circ$
M = .6 - .95, $= 16^\circ - 72.5^\circ$

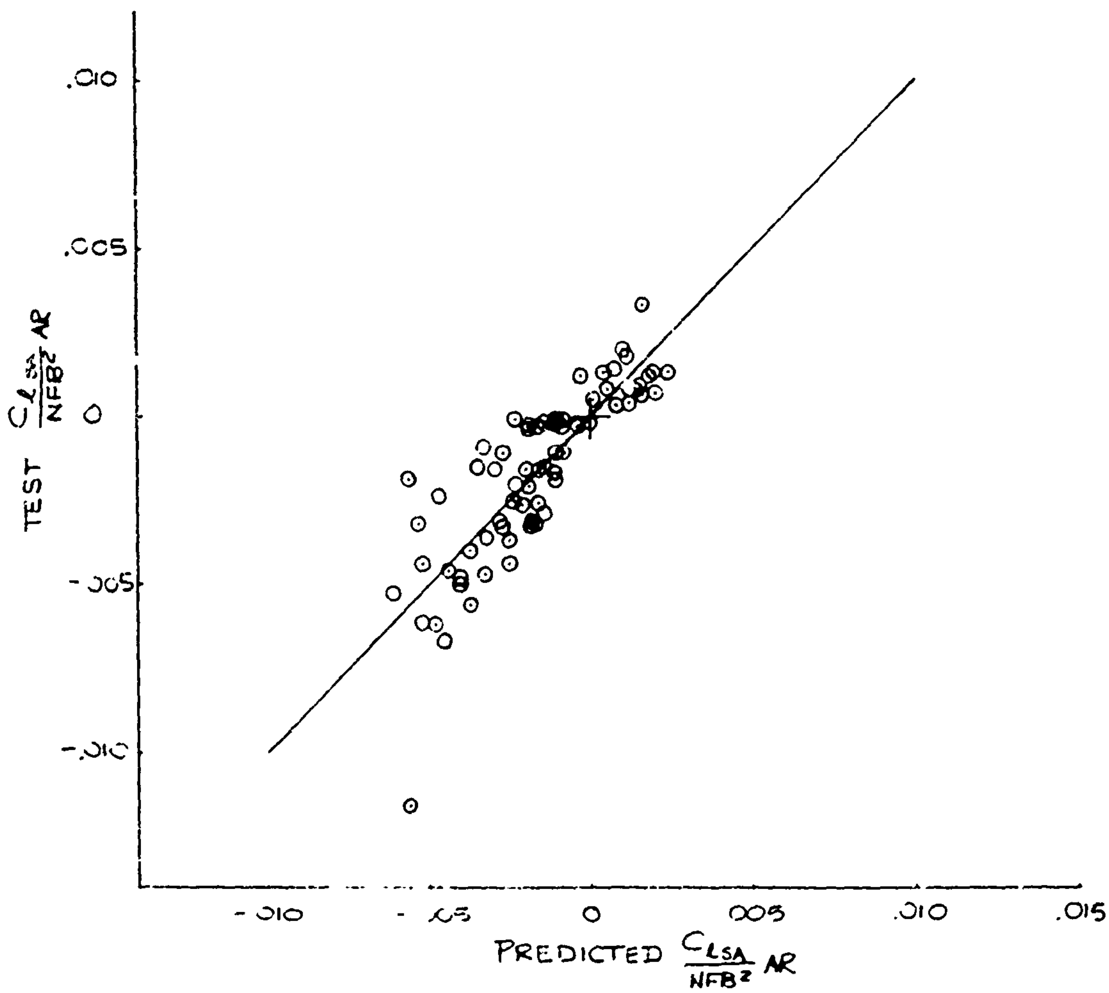
$$\frac{C_{\ell_{SA}}}{NFB^2} AR = -.0286329 - .0000174\ell - .0008097D + .0003244C + .0000545\Delta X + .0000162\frac{SA}{FA} \times FSPD + .0006133M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
INBOARD
ROLLING MOMENT COEFFICIENT

$\alpha = -4^\circ, \quad \beta = 0^\circ$
$M = .6 - .95, \quad \Lambda_{LE} = 16^\circ - 72.5^\circ$

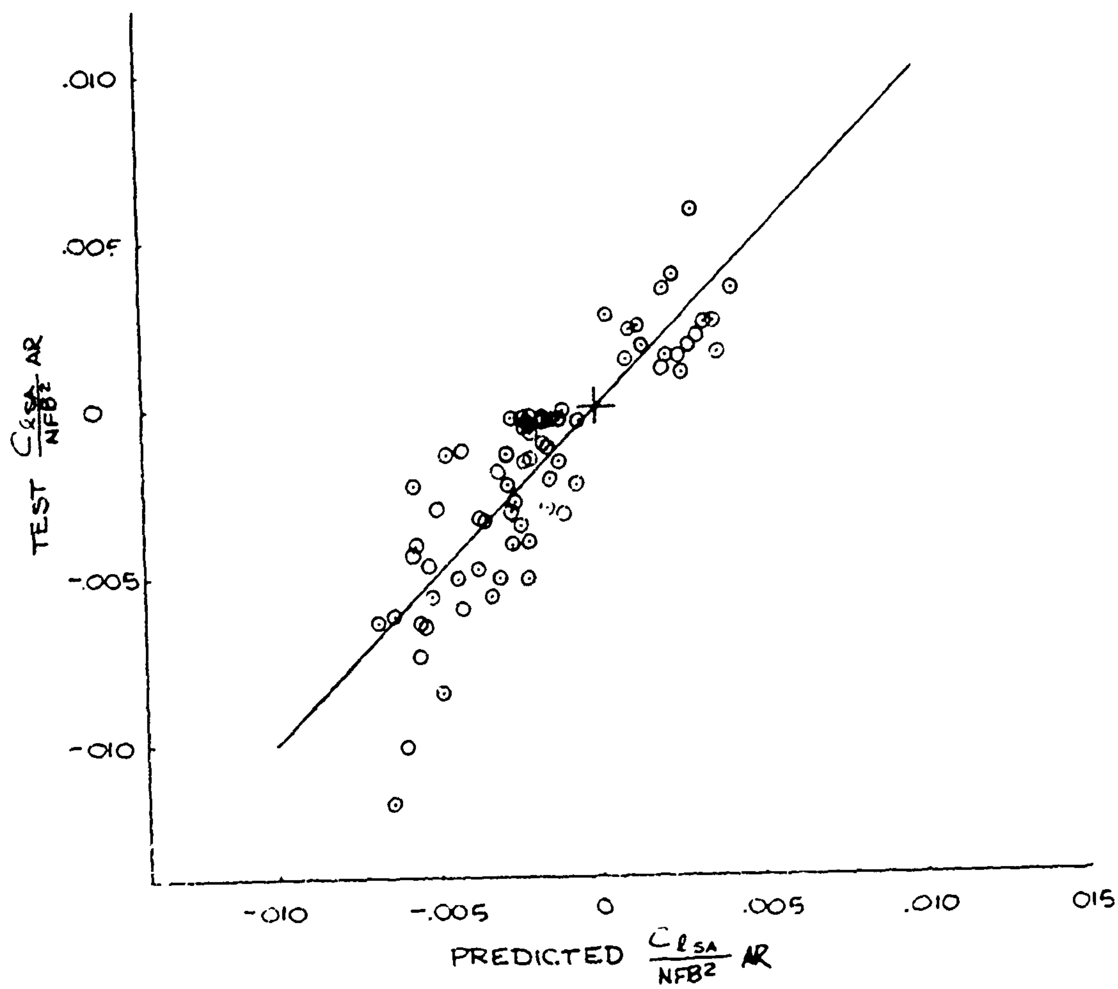
$$\frac{C_{\ell\,SA}}{NFB^2}\,AR = -.0293826 + .0000622\ell - .0007468D + .0002578C - .0000139\Delta X + .0000158\frac{SA}{FA} \times FSPD + .0012512M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
INBOARD
ROLLING MOMENT COEFFICIENT

$\alpha = -9^\circ, \ \beta = 0^\circ$
$M = .6 - .95, \ \Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{\ell SA}}{NFB^2}\ AR = -.0276649 + .0000932\ell - .0008904D + .0002356C - .0000166\Delta X + .0000158\ \frac{SA}{FA} \times FSPD + .0018532M^2$$

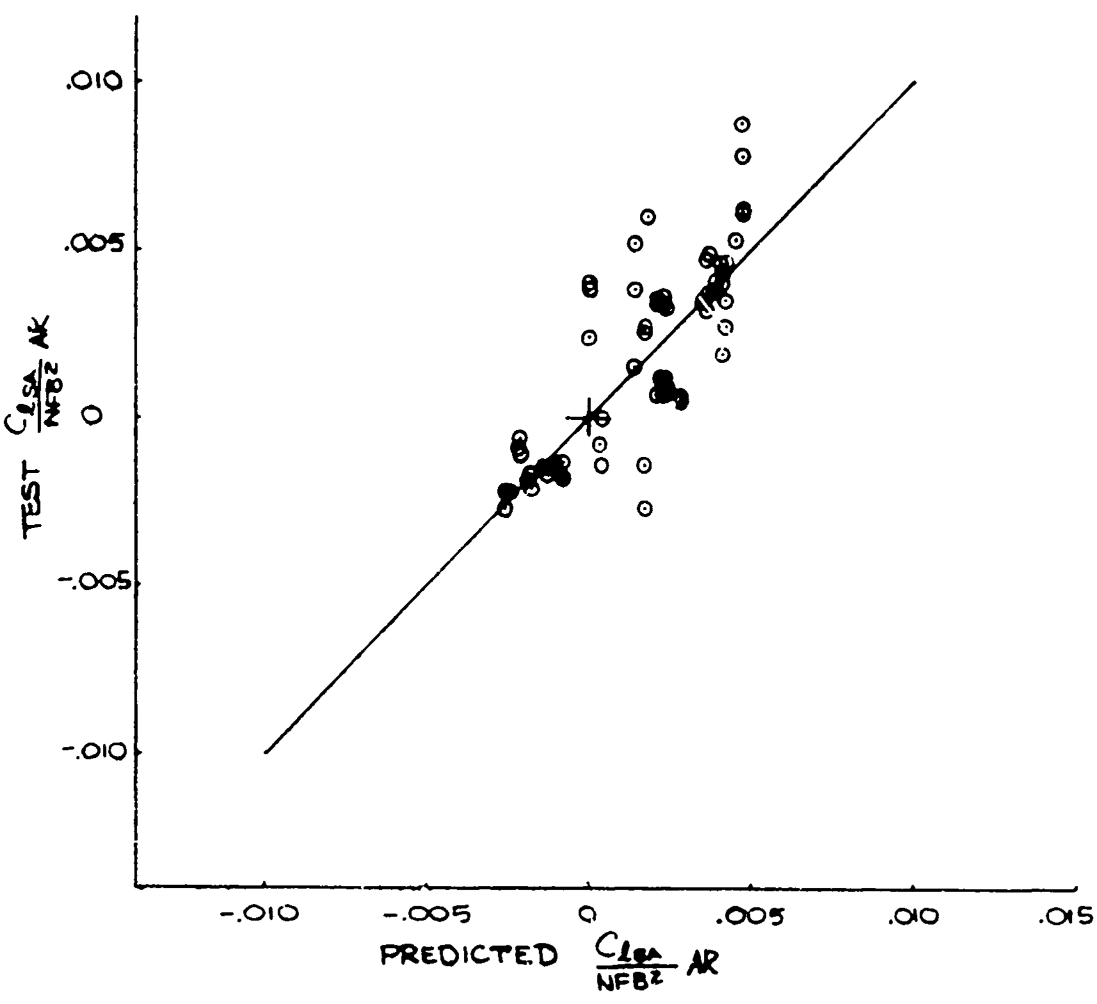


COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
INBOARD
ROLLING MOMENT COEFFICIENT

$$\alpha = 6^\circ, \quad \beta = 10^\circ$$

$$M = .6 - .95, \Lambda_{LE} = 16^\circ - 72.5^\circ$$

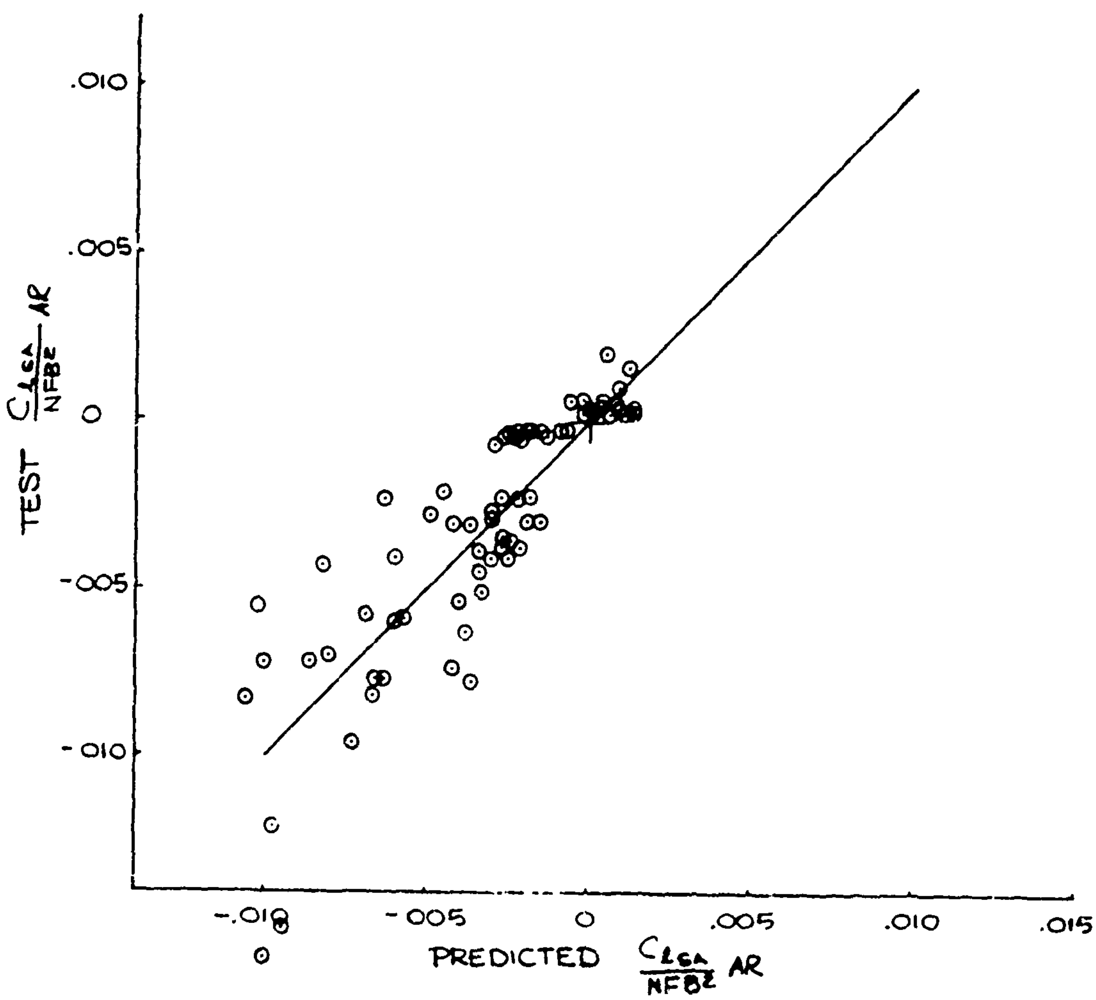
$$\frac{C_{l_{SA}}}{NFB^2} AR = -.0295305 - .0001521 + .0006012D + .0002629C$$
$$+ .0001151\Delta X + .0000109 \frac{SA}{FA} \times FSPD - .0001057M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK + PYLON
INBOARD
ROLLING MOMENT COEFFICIENT

$\alpha = 6^{\circ}, \ \beta = -10^{\circ}$
$M = .6 - .95, \ \Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{l_{SA}}}{NFB^2} AR = -.0068514 + .0001296\ell - .0033636D + .0003668C + .0000152\Delta X + .0000198 \frac{SA}{FA} \times FSPD + .0009738M^2$$



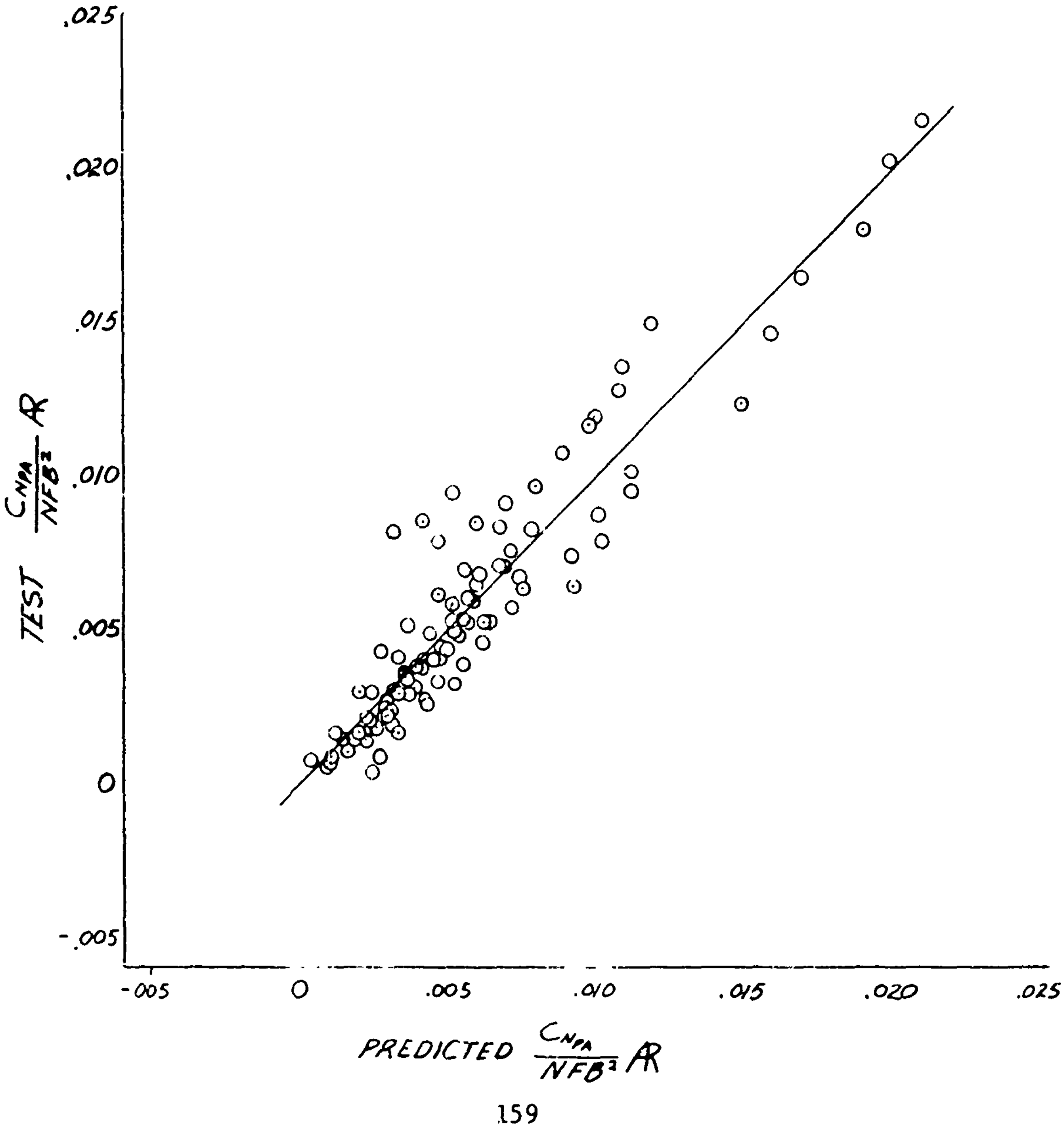
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = 16^o, \ \beta = 0^o$

$M = .60 - .95$

$\Lambda_{LE} = 16^o - 72.5^o$

$$\frac{C_{N_{PA}}}{NFB^2} AR = .0464159 + .0001782\ell - .0032068D - .0000263C - .0001578\Delta X + .0000101 \frac{PA}{FA} \times FSPD - .0036218M^2$$



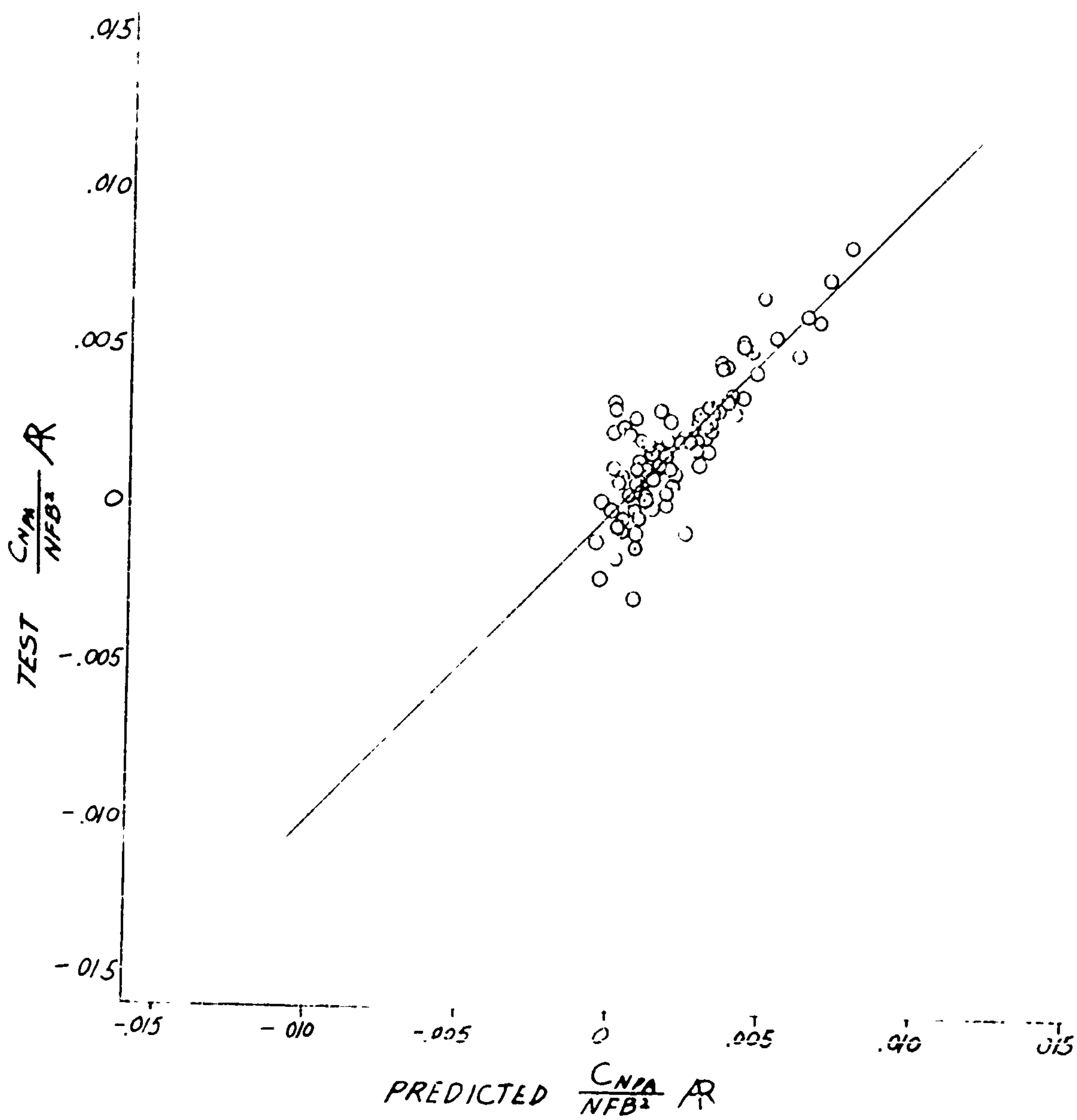
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = 6^\circ, \ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{N_{PA}}}{NFB^2} AR = .0290903 + .0001389\ell - .0018504D - .0000512C - .0001611\Delta X - .0000035 \frac{PA}{FA} \times FSPD - .0026321M^2$$



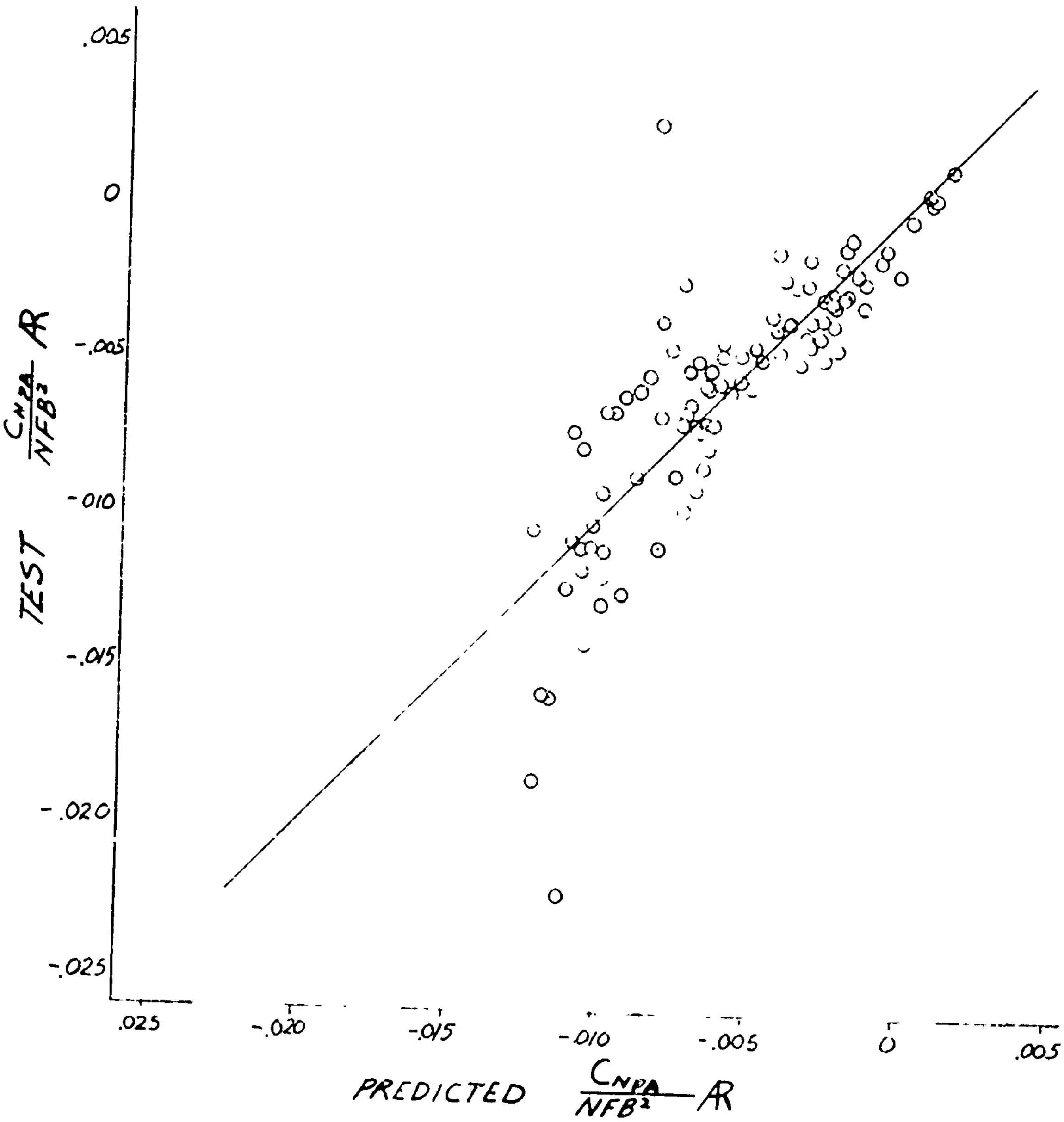
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = -4^{\circ}, \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{N_{PA}}}{NFB^2} AR = .0649270 + .0002027\ell - .0040564D - .0000682C - .00014544X - .0000029 \frac{PA}{FA} \times FSPD - .0144923M^2$$



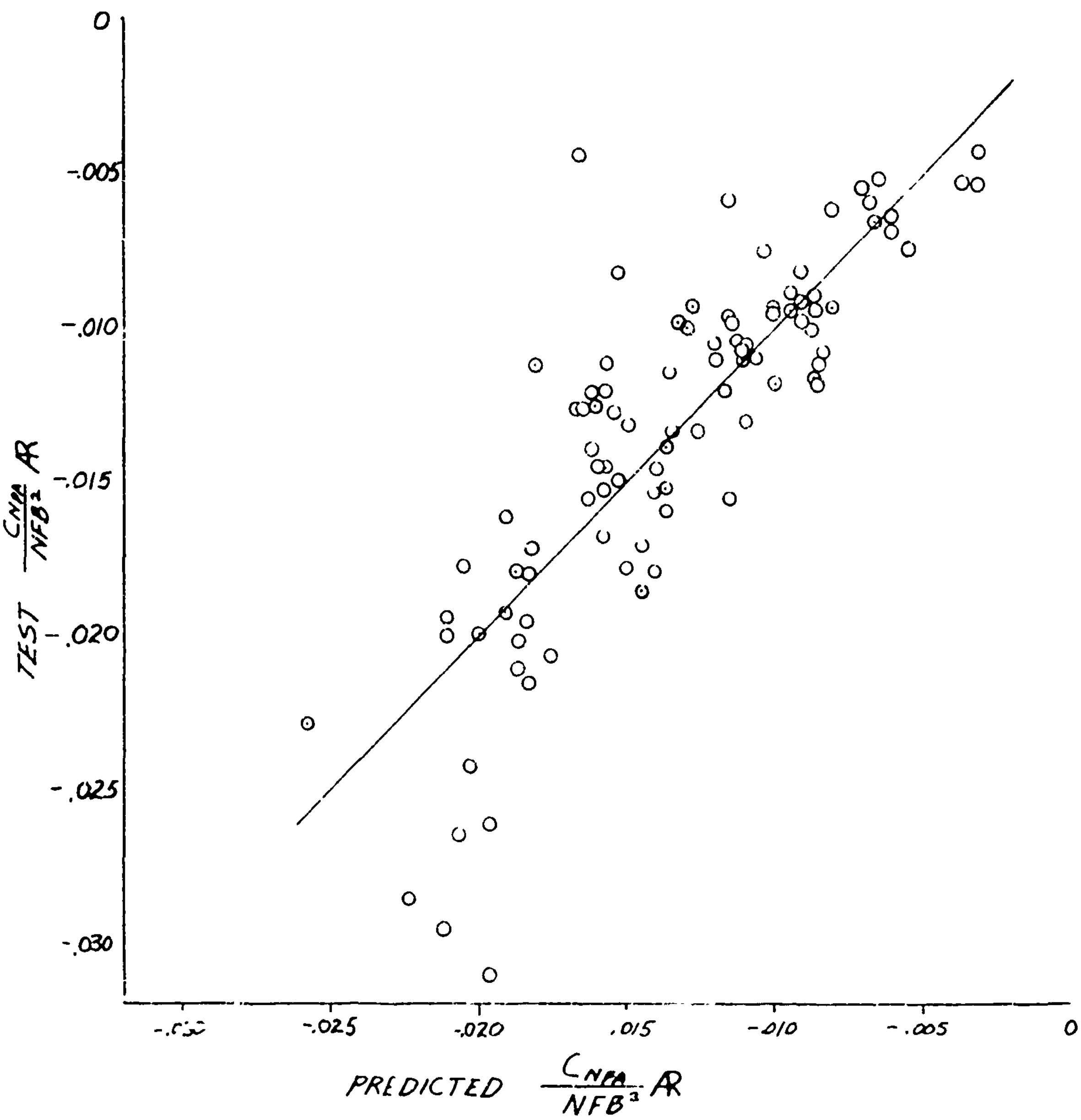
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = -9^{\circ}, \ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{N_{PA}}}{NFB^2} AR = .1222551 + .0003240\ell - .0078883D - .0001218C - .0002146\Delta X - .0000066 \frac{PA}{FA} \times FSPD - .0176933M^2$$



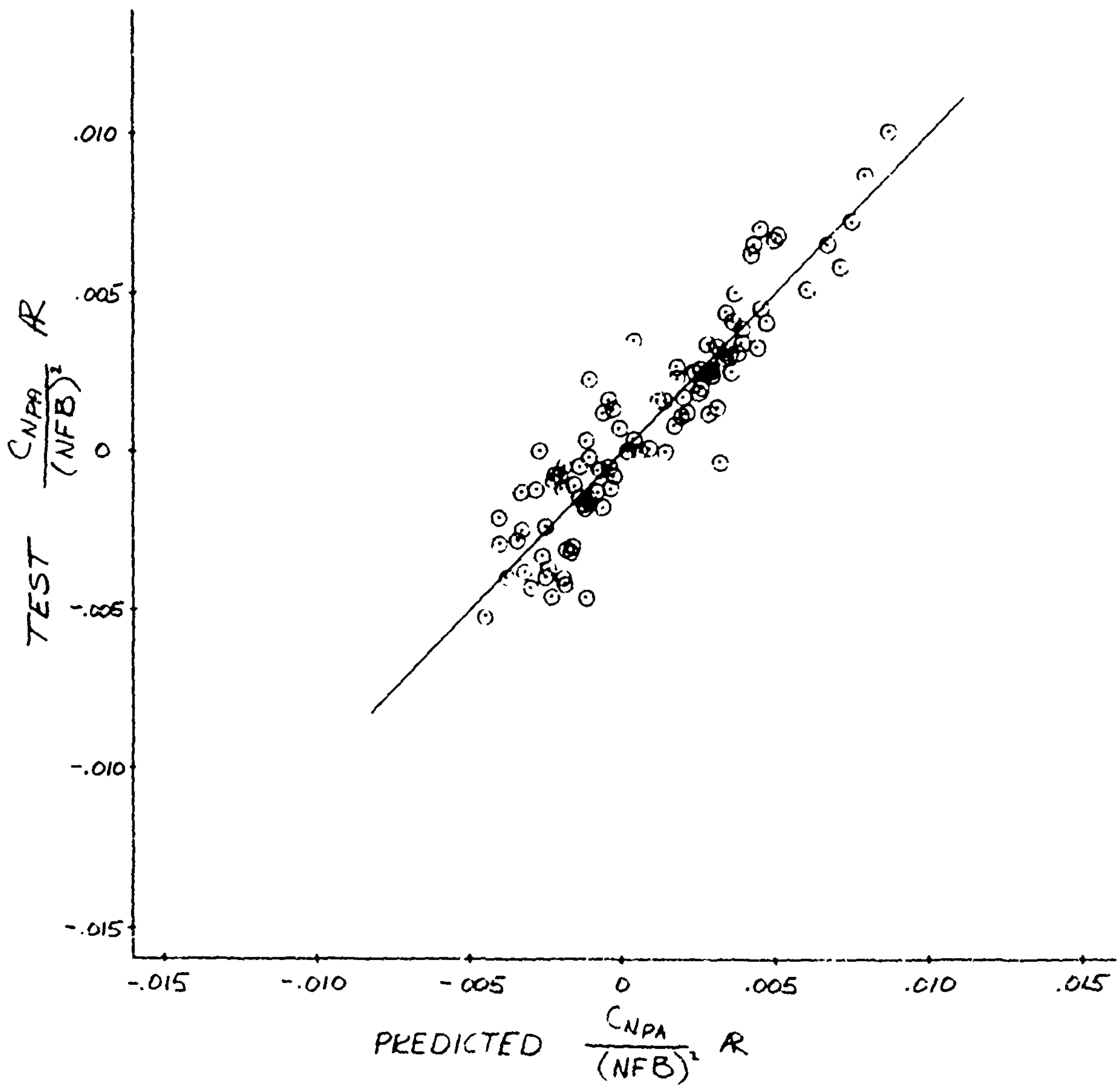
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = 6^{\circ},\ \beta = +10^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

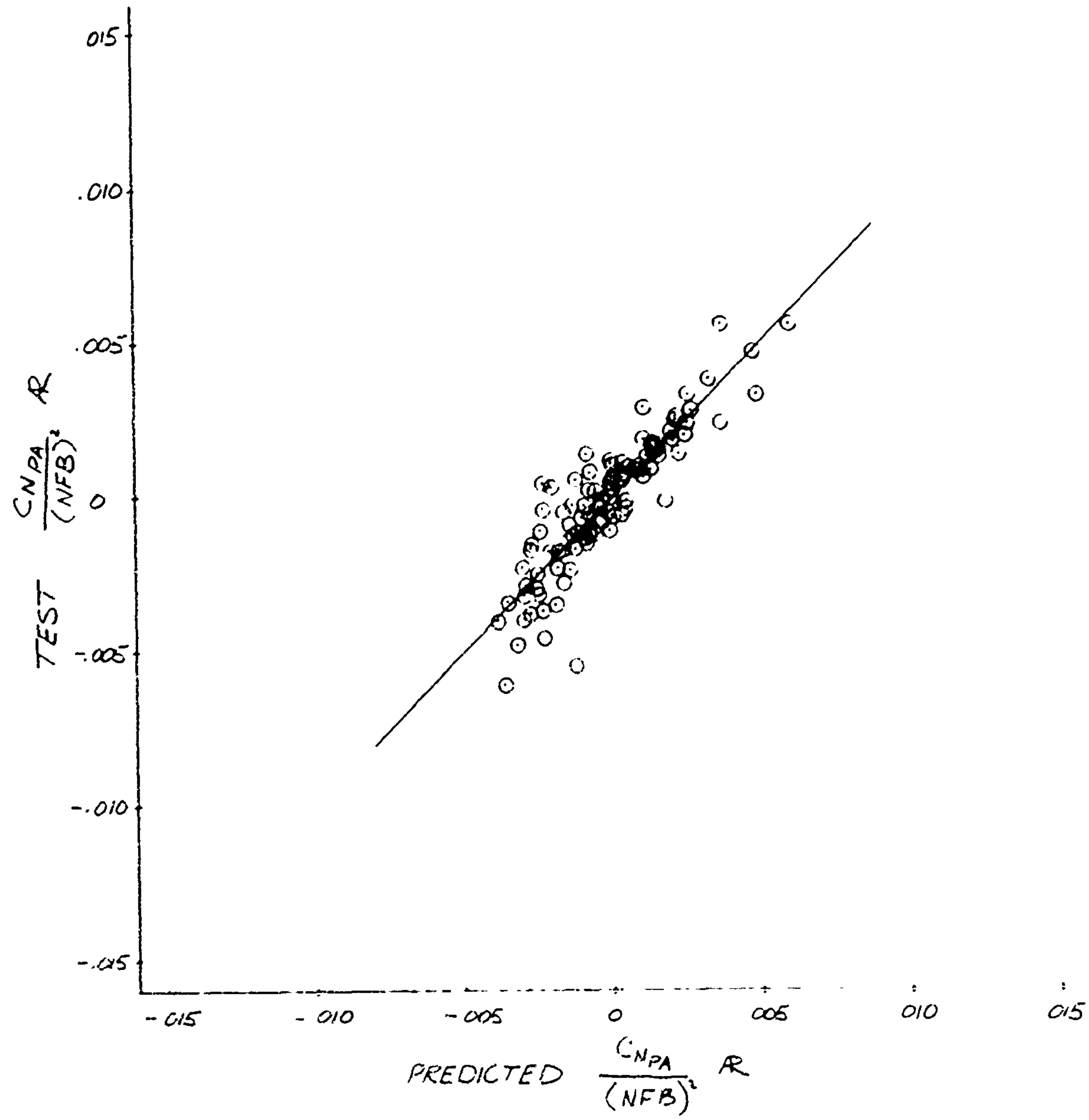
$$\frac{C_{N_{PA}}}{NFB^2} AR = .0800672 + .0002802\ell - .005772D - .0000538C - .0001895\Delta X + .0000042 \frac{PA}{FA} \times FSPD - .0028644M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
NORMAL FORCE COEFFICIENT

$$\alpha_{LOAD} = 6^{\circ},\ \beta = -10^{\circ}$$
$$M = .60 - .95$$
$$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$$

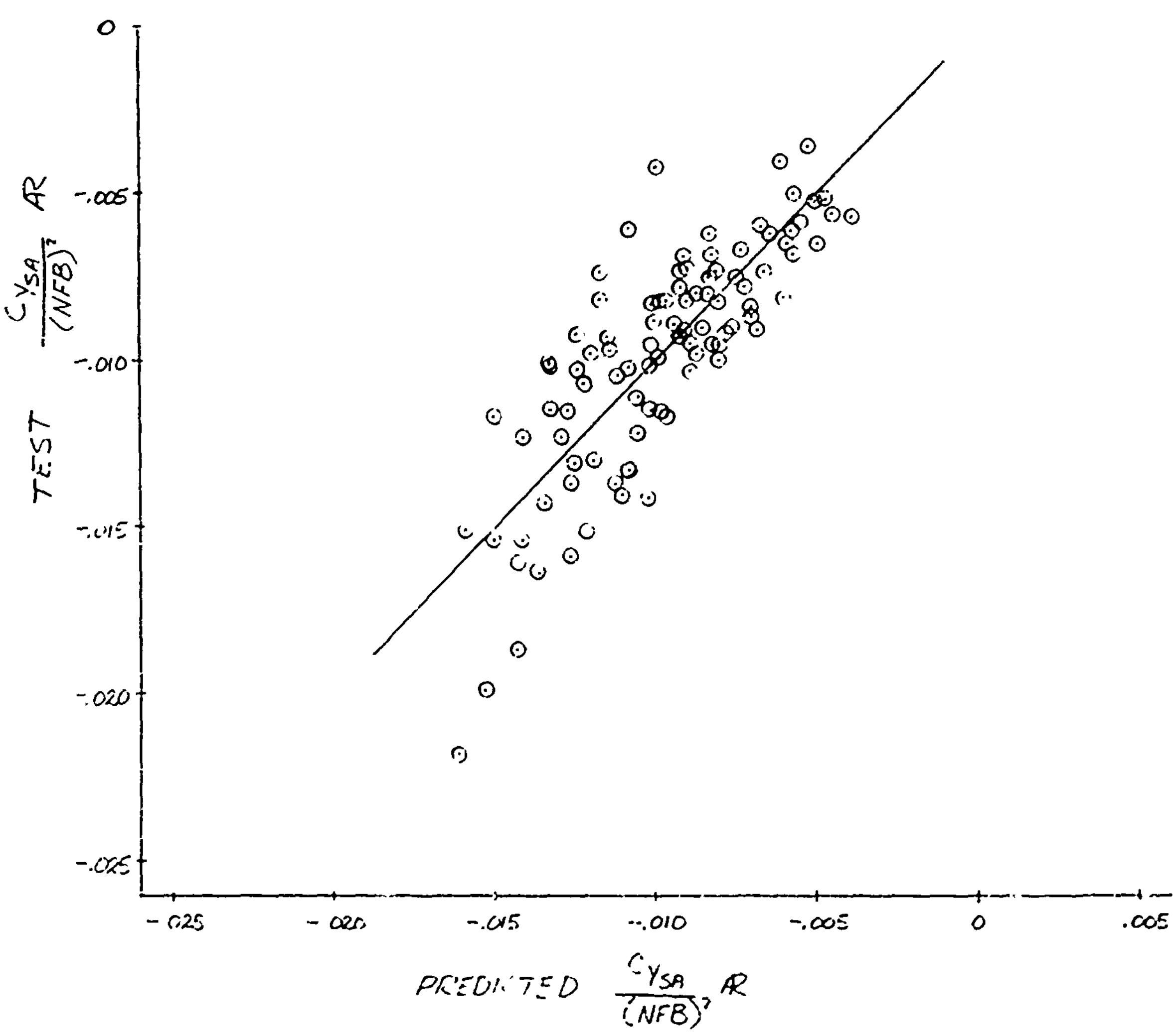
$$\frac{C_{N_{PA}}}{NFB^2} AR = .0490430 + .0001690\,\ell - .0033375D - .0000448C$$
$$-.0001422\Lambda X + .000034 \frac{PA}{FA} \times FSPD - .0041177M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
SIDE FORCE COEFFICIENT

$$\alpha_{LOAD} = 16^\circ,\ \beta = 0^\circ$$
$$M = .60 - .95$$
$$\Lambda_{LE} = 16^\circ - 72.5^\circ$$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = .1338657 + .0002782\,\ell - .0073283D - .0002927C - .0002682\Delta X - .000015? \frac{SA}{FA} \times FSPD - .0033665M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK

Outboard

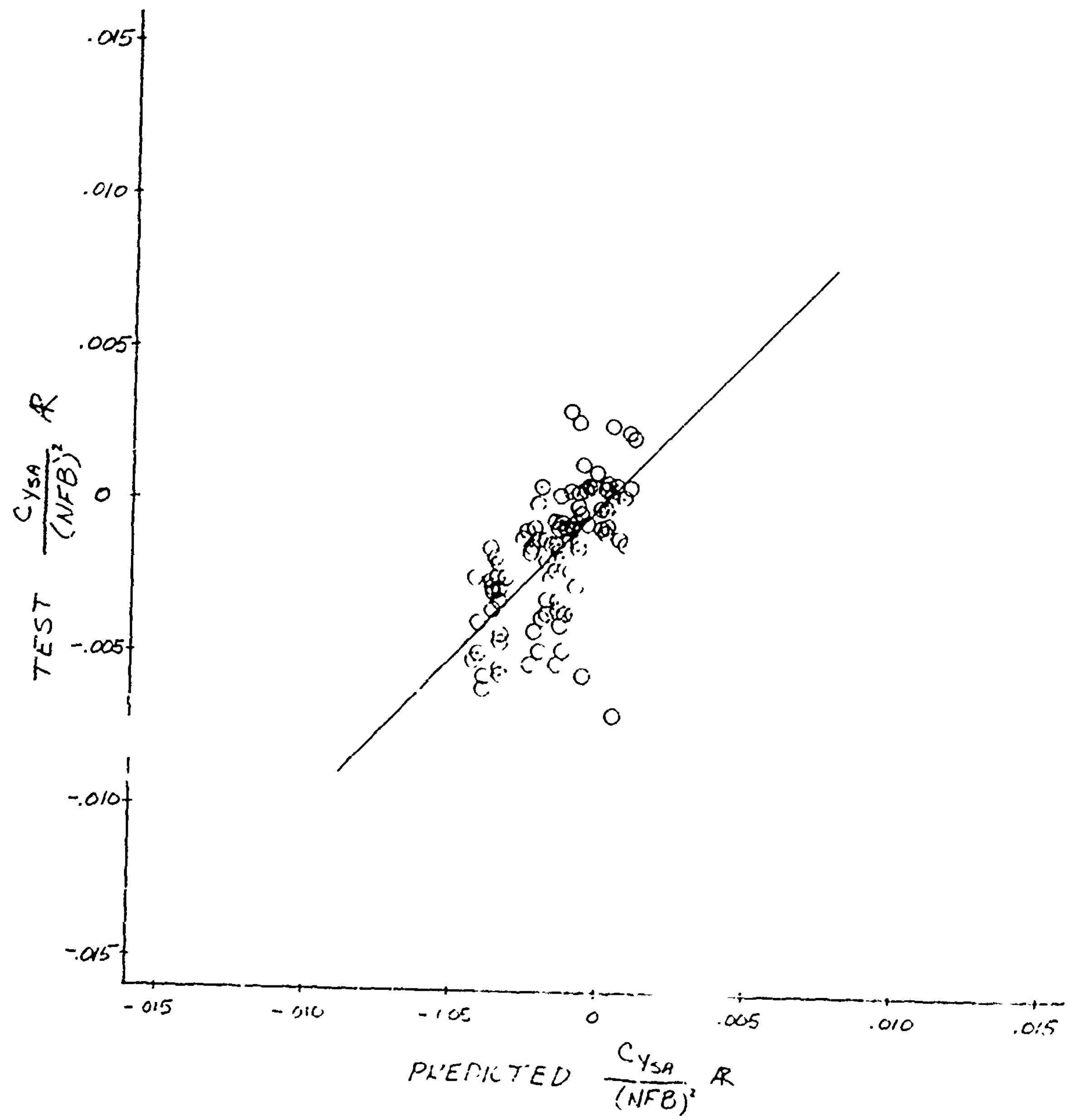
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = 6^\circ, \ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = .0069187 + .0001266\ell + .0002836D - .0001649C - .0001971\Delta X - .0000088 \frac{SA}{FA} \times FSPD + .0005366M^2$$



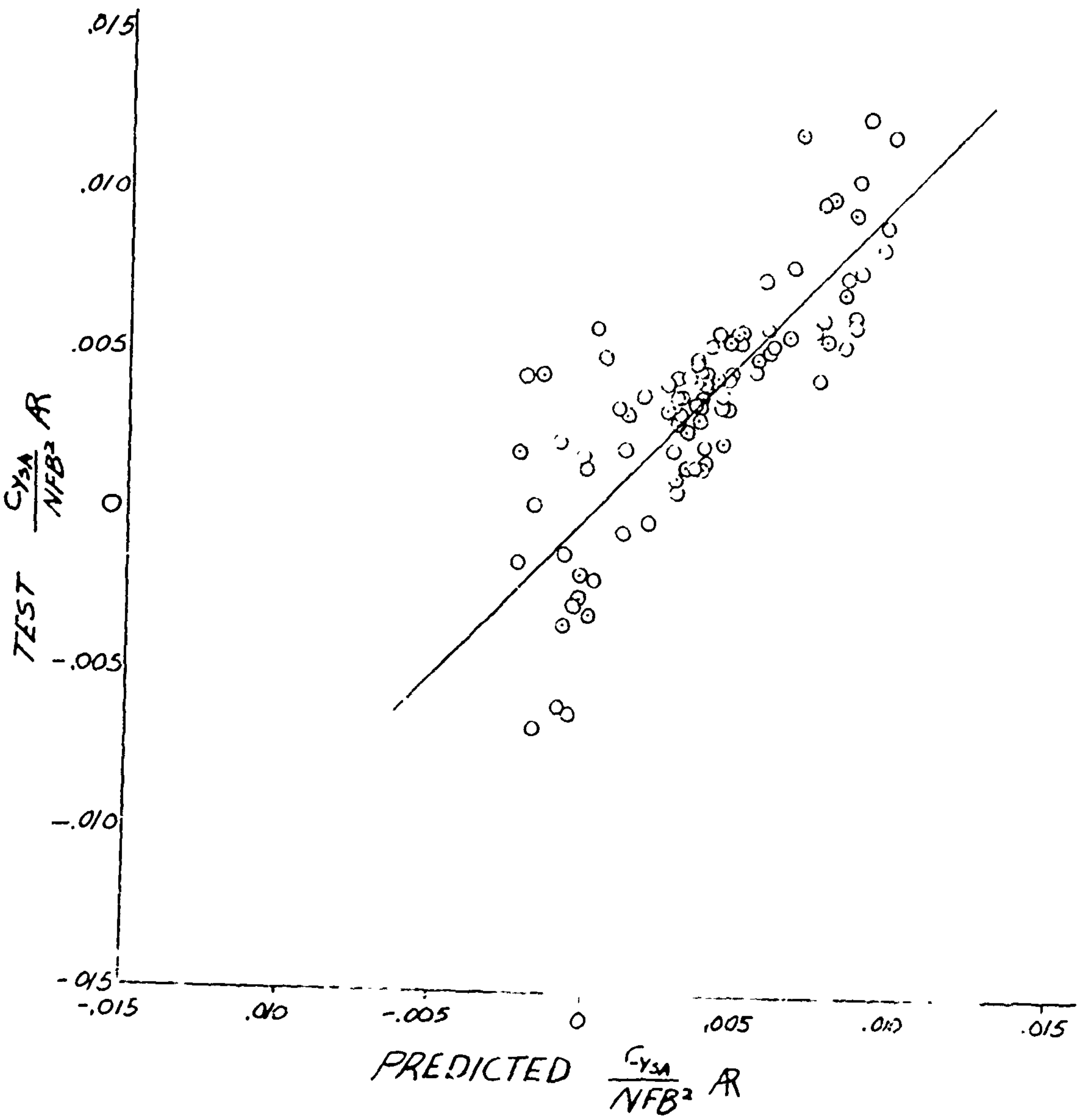
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = -4^{\circ}, \ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = .0451153 + .0001769\,\ell - .0036213D + .0000300C + .0000003\Delta X - .0000015\,\frac{SA}{FA} \times FSPD + .0006152M^2$$



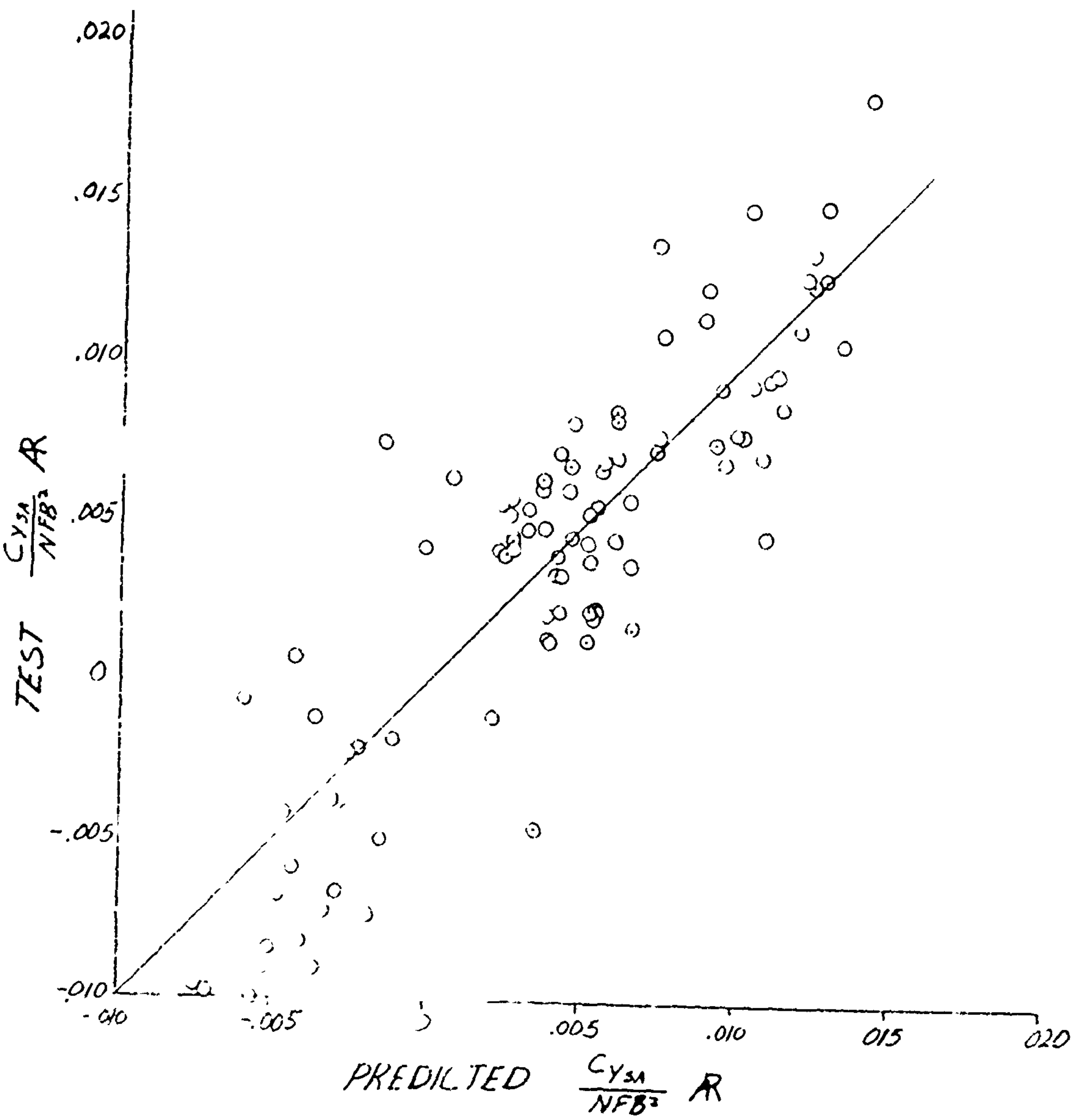
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = -9^{\circ},\ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = .0823196 + .0002618\,\mathcal{L} - .0071981D + .0001151C + .0001056 7\Delta X + .0000021\,\frac{SA}{FA} \times FSPD + .0052640M^2$$



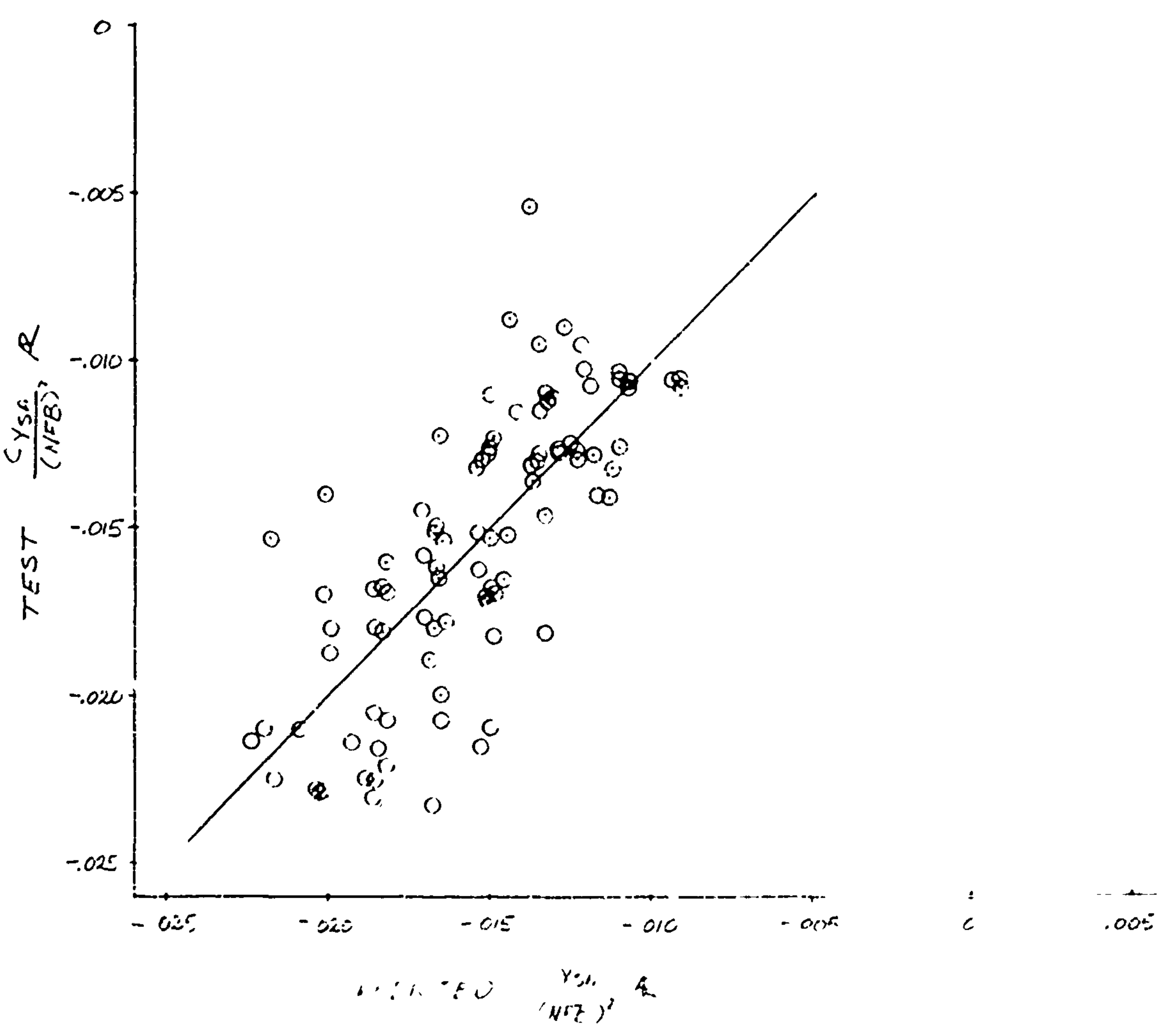
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = 6^\circ, \beta = +10^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = .1040386 + .0002619\,\ell - .0065211D - .0001936C - .0003258\Lambda X - .0000062\,\frac{SA}{FA} \times FSPD - .0058807M^2$$



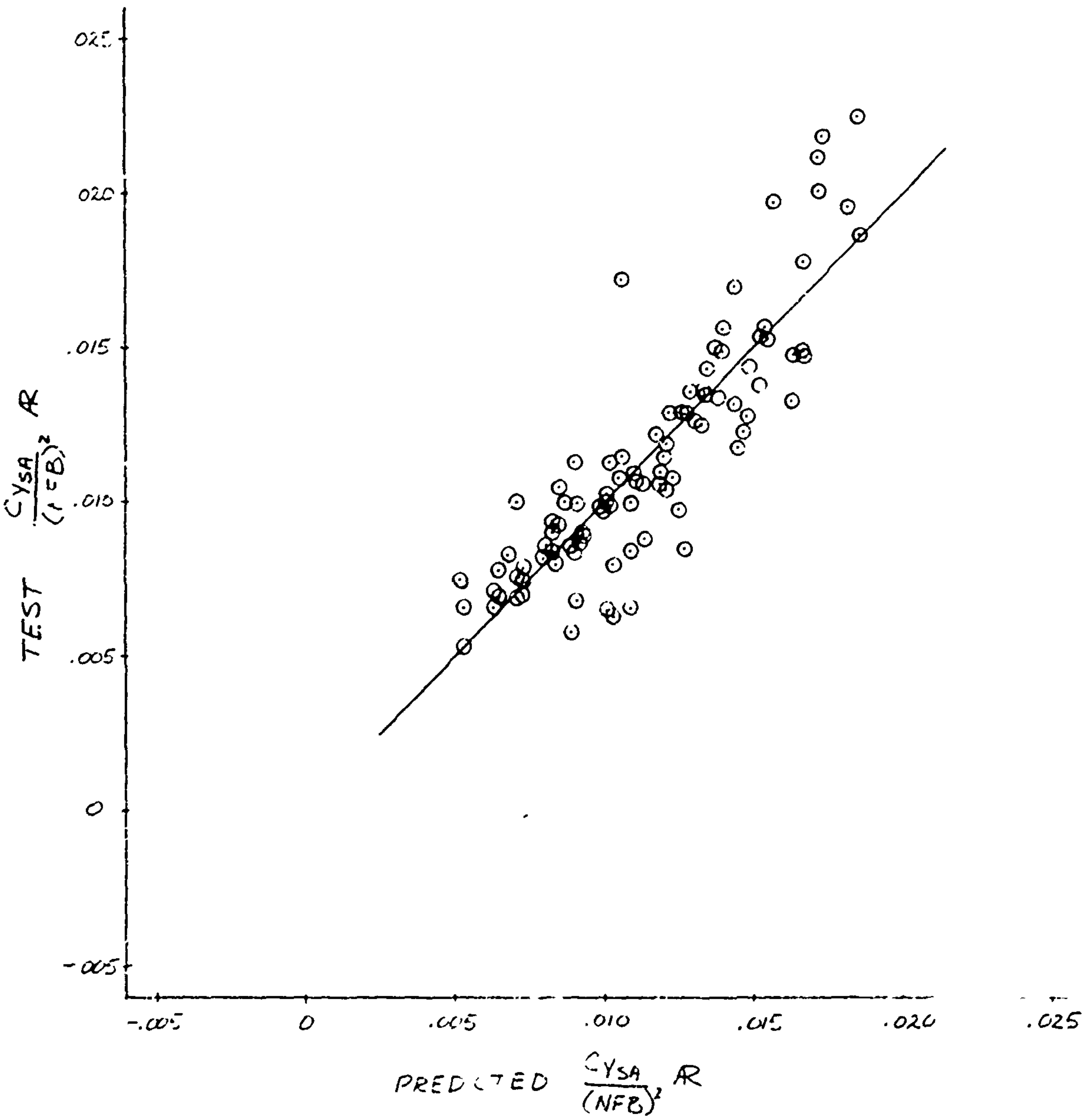
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \ \beta = -10^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = -.079380 + .0000062\,\ell + .0065318D - .0001634C - .0001620\Delta X - .0000087\,\frac{SA}{FA} \times FSPD + .0070115M^2$$



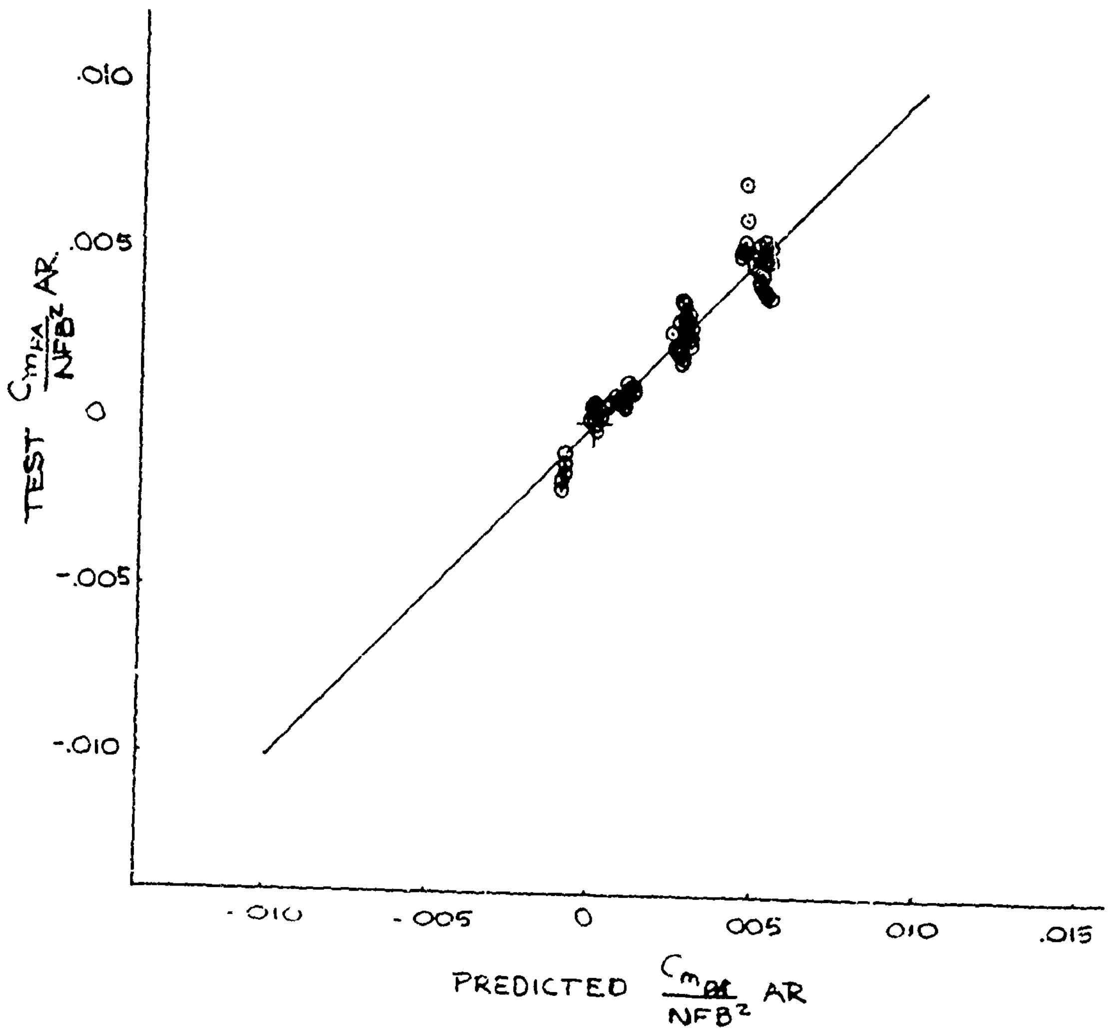
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
PITCHING MOMENT COEFFICIENT

$\alpha_{LOAD} = 16^\circ,\ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

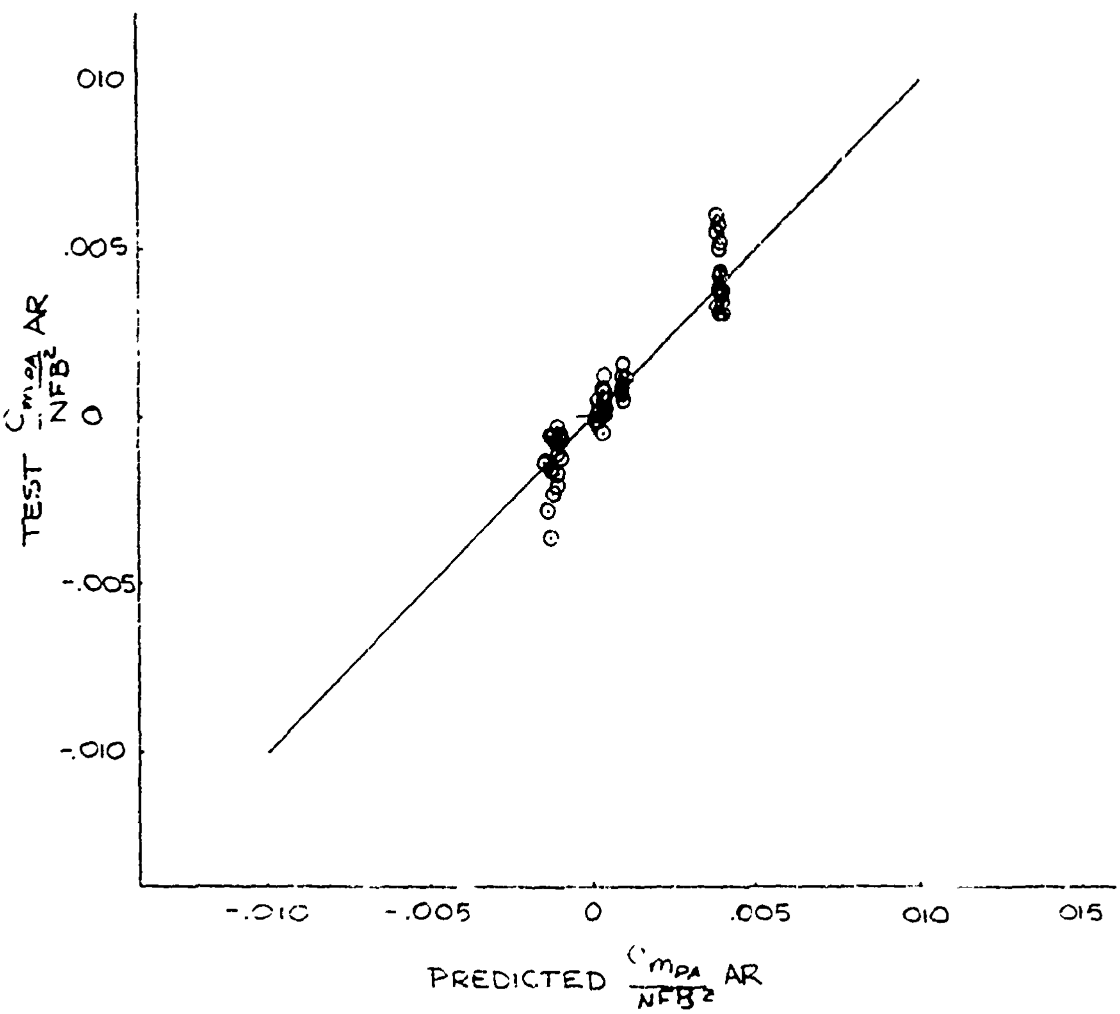
$$\frac{Cm_{PA}}{NFB^2} AR = -.0666221 - .0002063\lambda + .0048313D + .0004190 + .0000857\Delta X - .0000005 \frac{PA}{FA} \times FSPD + .0001216M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
PITCHING MOMENT COEFFICIENT

$$\alpha_{LOAD} = 6^{\circ},\ \beta = 0^{\circ}$$
$$M = .60 - .95$$
$$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$$

$$\frac{C_{m_{PA}}}{NFB^2} AR = -.0581736 - .0001522\,\ell + .0043308D + .0000013C + .0000022\Delta X - .0000001\,\frac{PA}{FA} \times FSPD - .0001580M^2$$



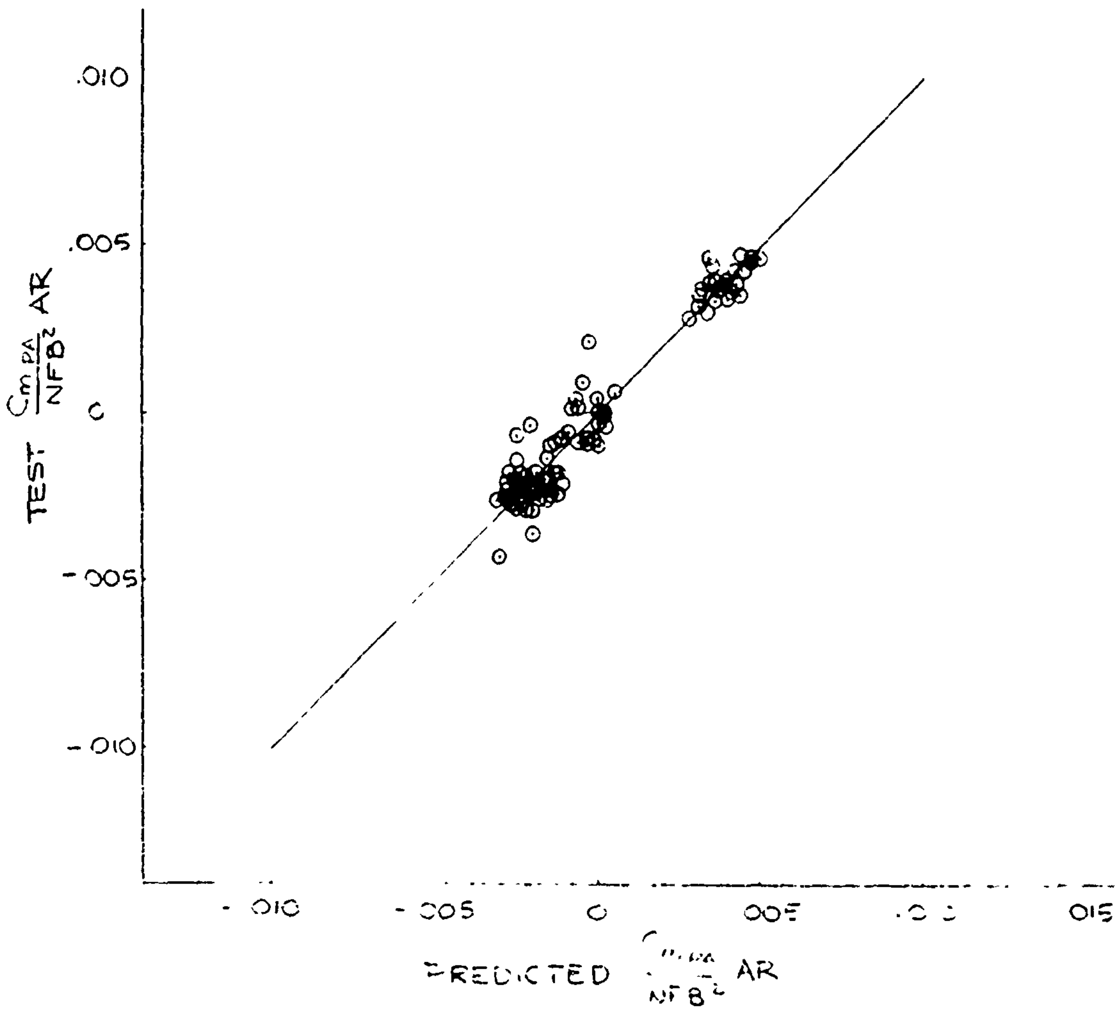
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
PITCHING MOMENT COEFFICIENT

$\alpha_{LOAD} = -4^{\circ}, \ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{m_{PA}}}{NFB^2} AR = -.0780703 - .0001051\ell + .0058759D - .0000831C - .0001659\Delta X + .0000001 \frac{PA}{FA} \times FSPD + .0010301M^2$$



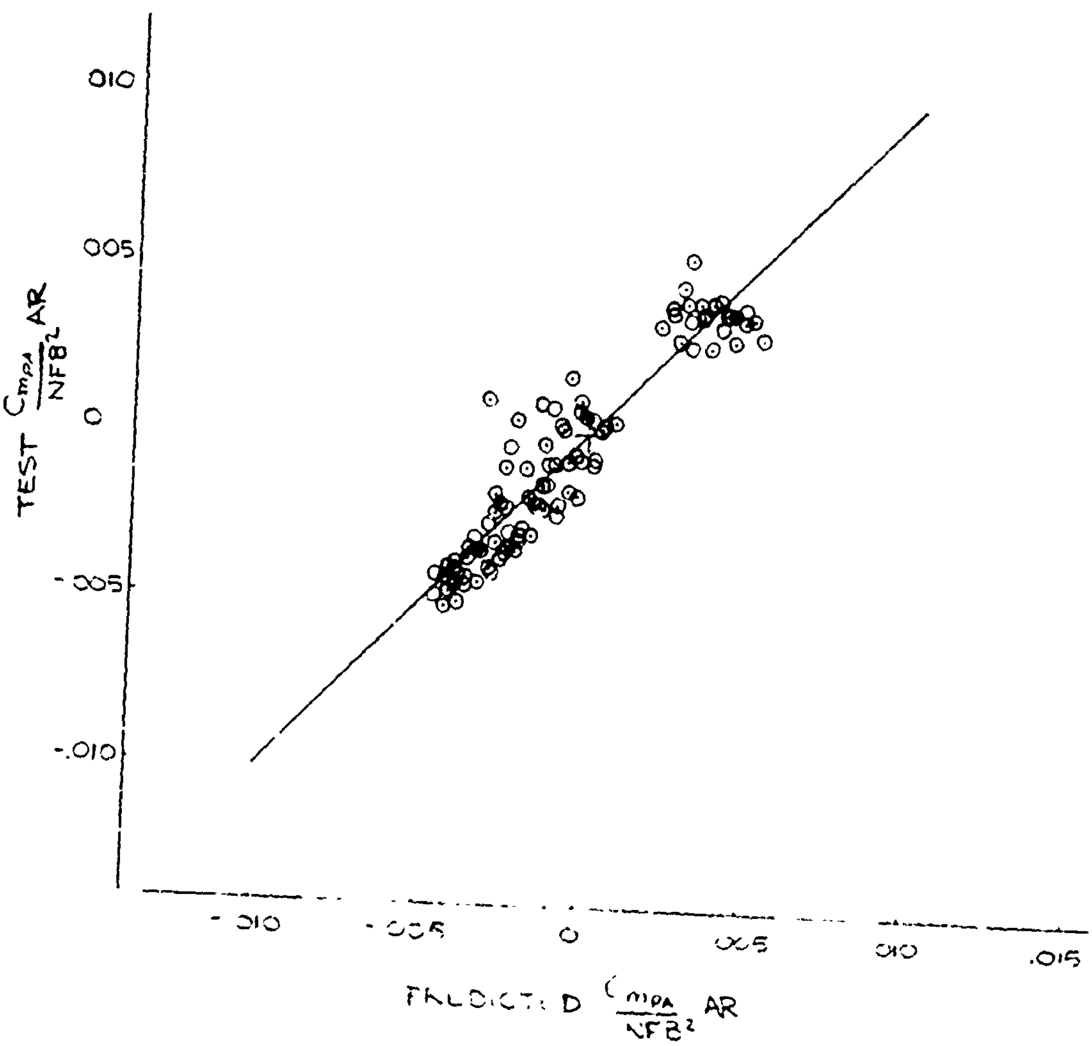
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
PITCHING MOMENT COEFFICIENT

$\gamma_{LOAD} = -9^{\circ},\ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{m_{PA}}}{NFB^2} AR = -.0851708 - .0000551\ell + .0064723D - .0001368C - .0002695\Delta X - .0000002 \frac{PA}{FA} \times FSPD + .0011138M^2$$



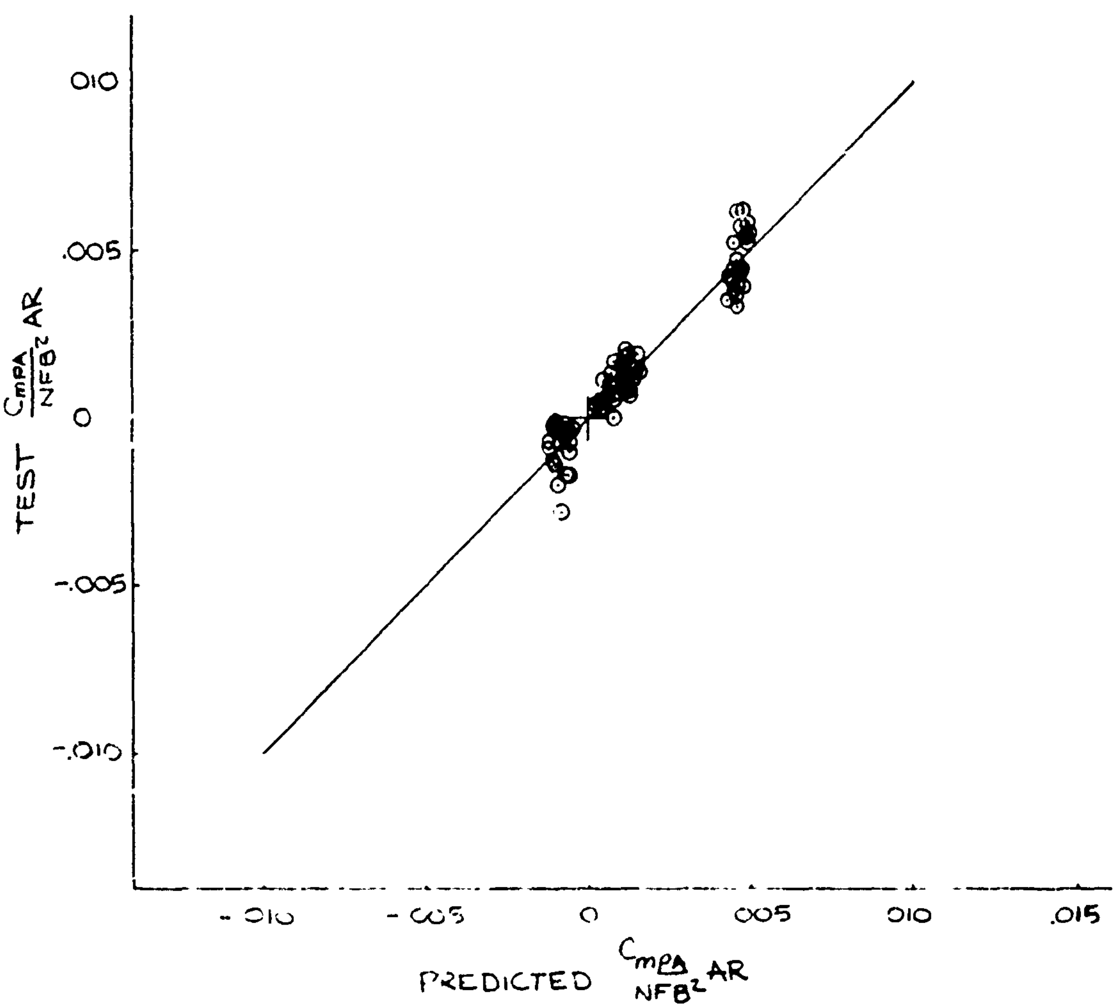
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
PITCHING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^\circ,\ \beta = +10^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{m_{PA}}}{NFB^2} AR = -.0674624 - .0001726\ell + .0049479D + .0000069C$$
$$+.0000057\Lambda X - 0\ \frac{PA}{FA} \times FSPD + .0005631M^2$$



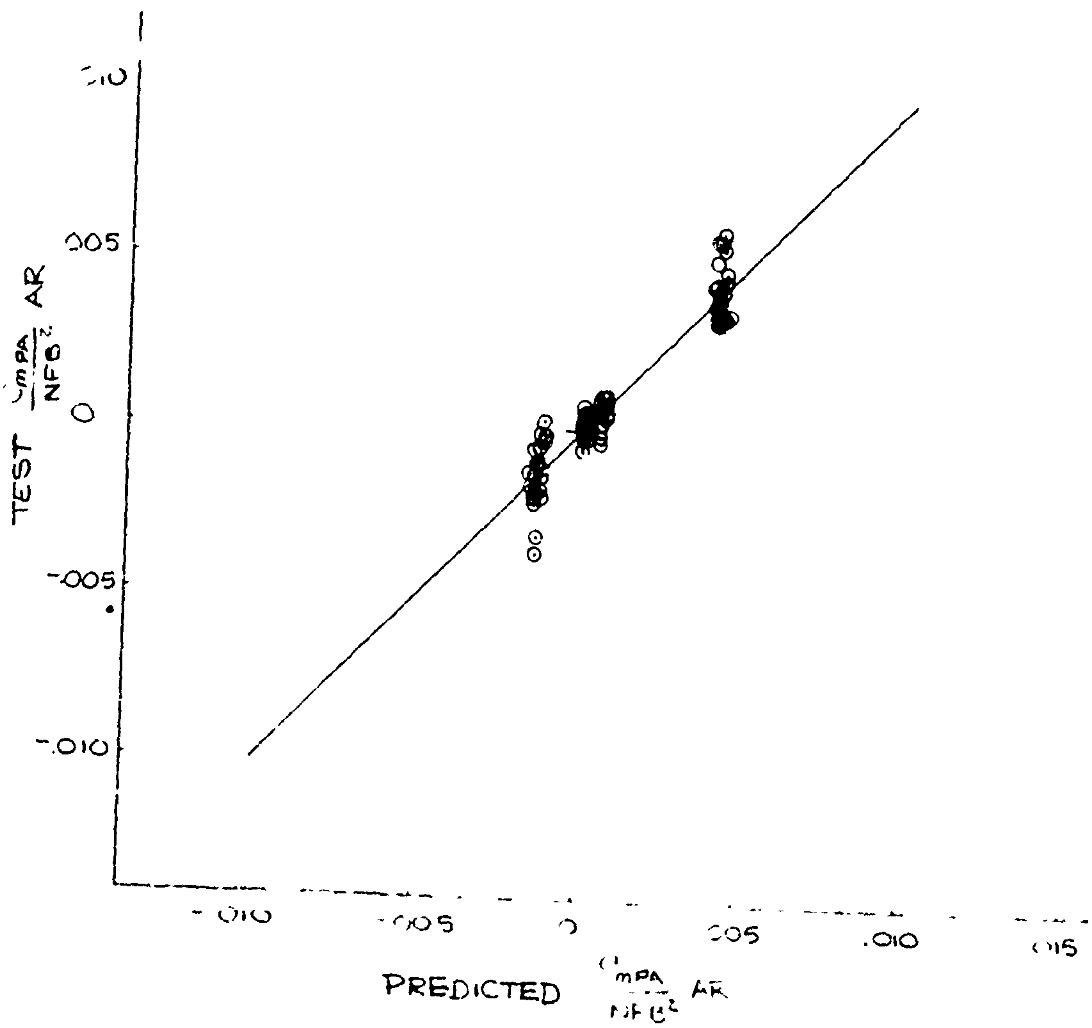
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
PITCHING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^\circ,\ \beta = -10^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{Cm_{PA}}{NFB^2} AR = -.0646210 - .0001621\beta + .0048569D - .0000101C$$
$$-.0000089\Lambda X - .0000002 \frac{PA}{FA} \times FSPD - .0003474M^2$$



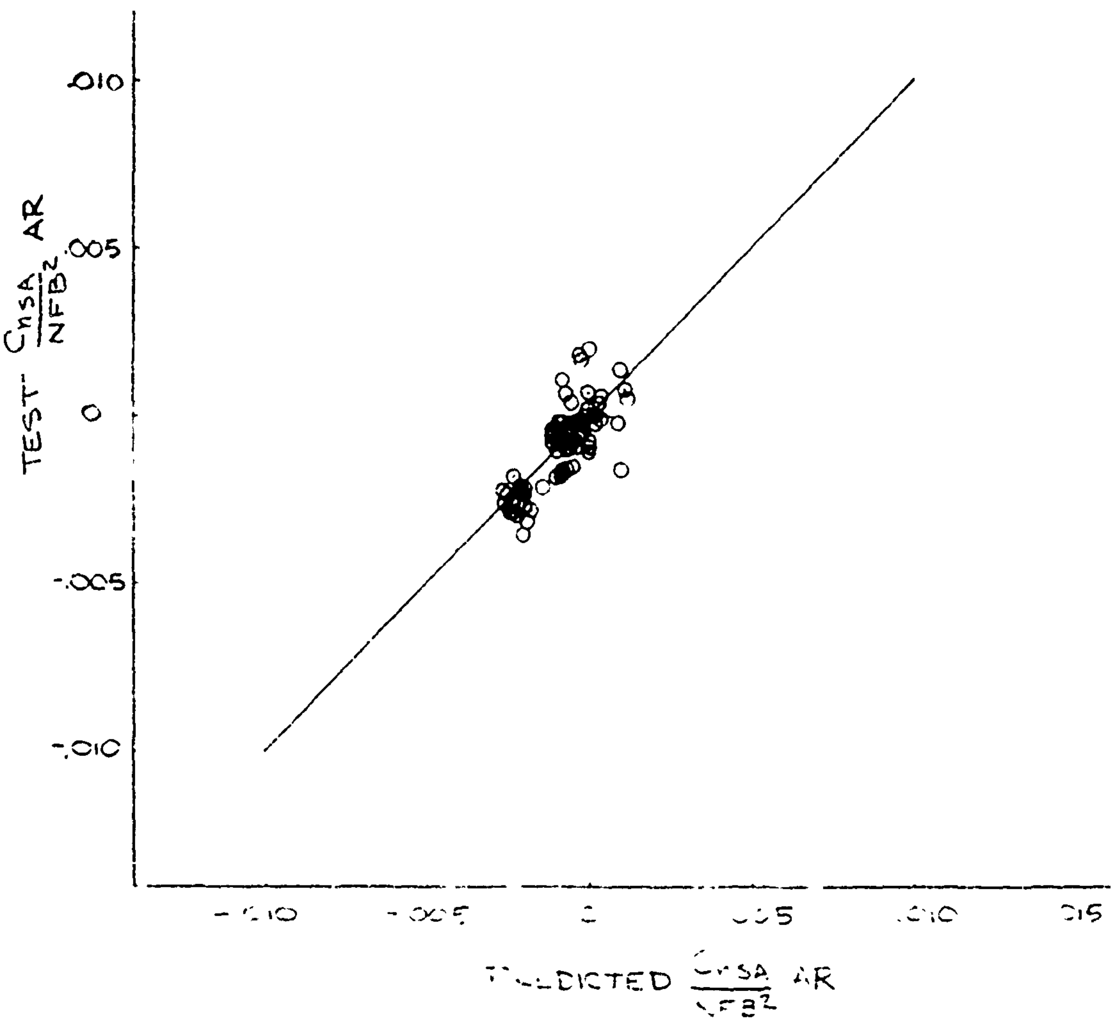
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = 16^{o}, \beta = 0^{o}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{o} - 72.5^{o}$

$$\frac{C_{n_{SA}}}{NFB^2} AR = -.0236781 + .0000205 + .0016124D - .0000432C - .0000969\,X + .0000021 \frac{SA}{FA} \times FSPD - .0005368M^2$$



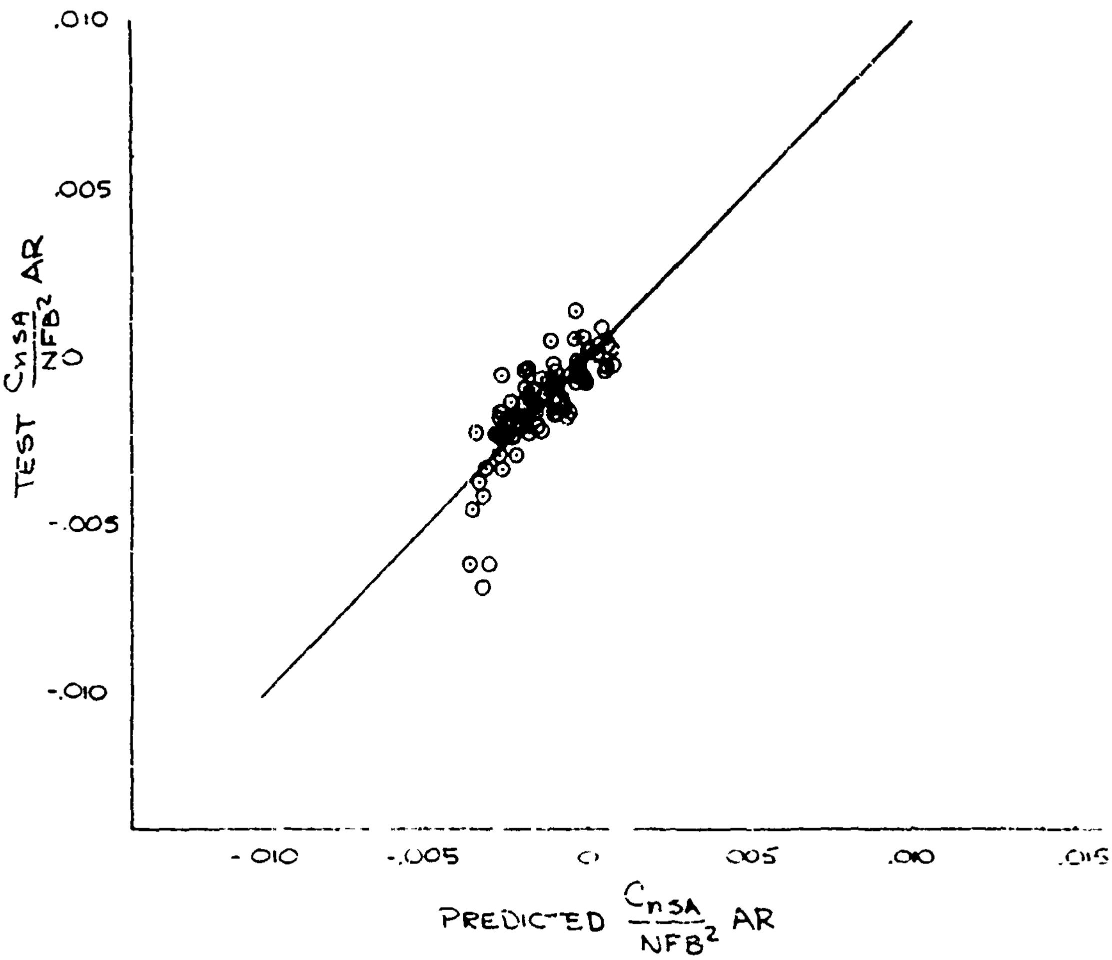
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{n_{SA}}}{NFB^2} AR = .0043273 - .0000071\alpha + .0005849D - .0000290C - .0000583\Lambda X - .0000002\frac{SA}{FA} \times FSPD - .0029647M^2$$



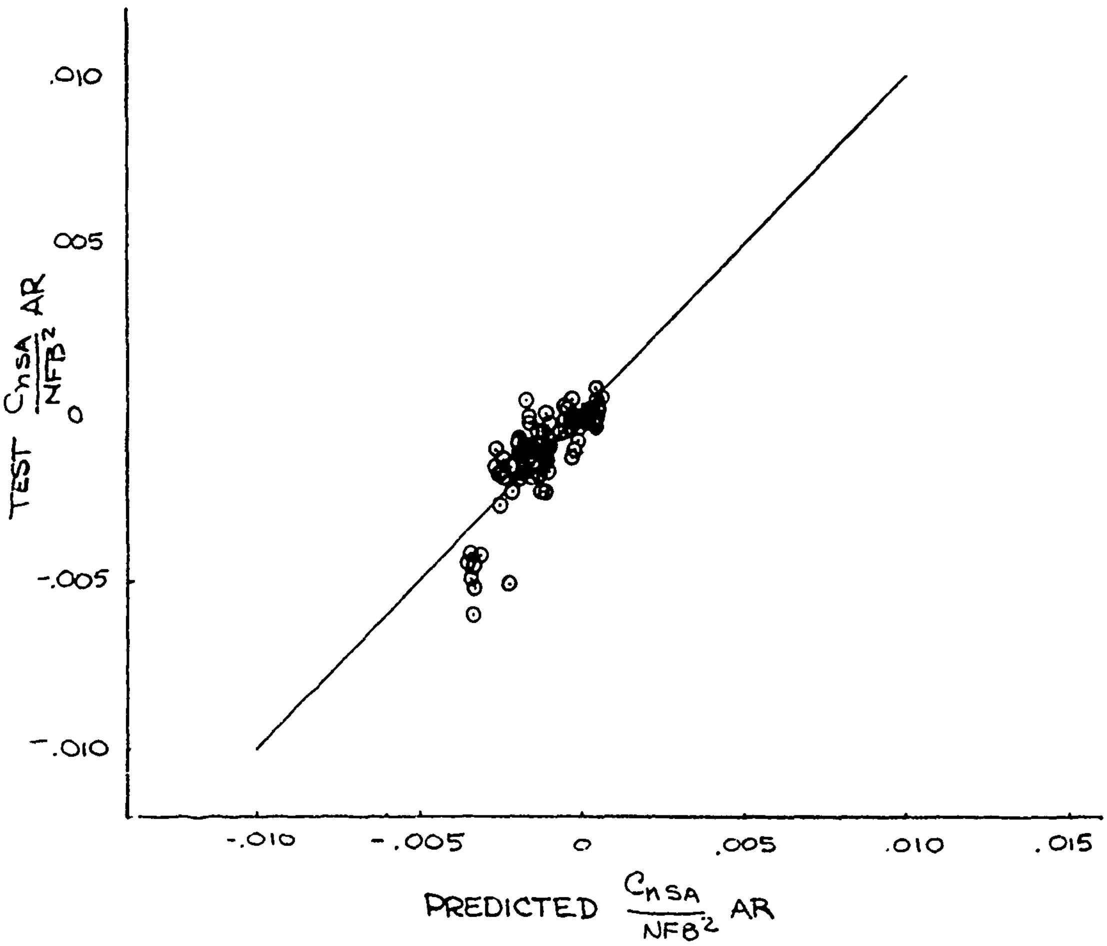
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = -4^\circ, \ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{n_{SA}}}{NFB^2} AR = .0368192 + .0000303\ell - .0022323D - .0000063C + .0000044JX - .0000012 \frac{SA}{FA} \times FSPD - .0031355M^2$$



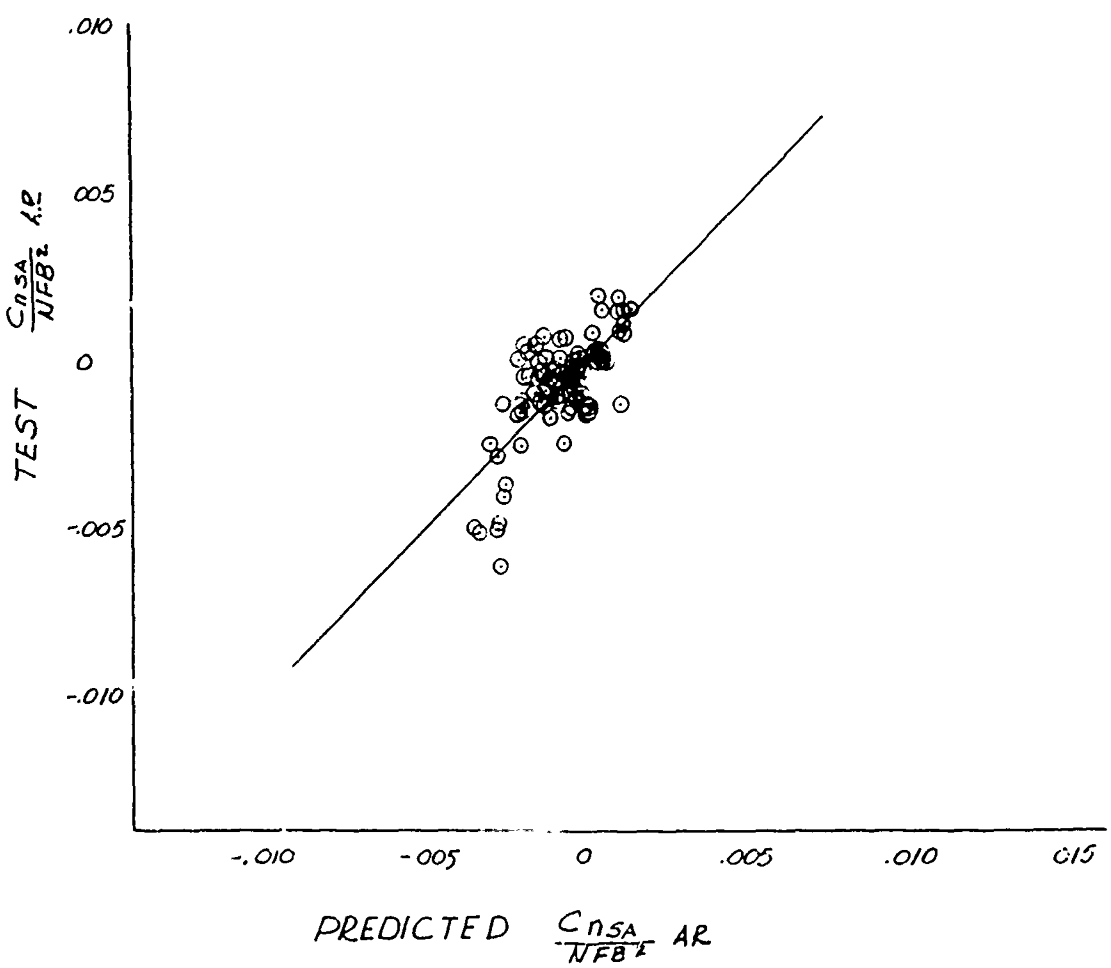
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = -9^{\circ}, \ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{n_{SA}}}{NFB^2} AR = .0362629 + .0000131\ell - .0022810D + .0000158C + .0000419\Delta X - .0000015 \frac{SA}{FA} \times FSPD - .0026786M^2$$



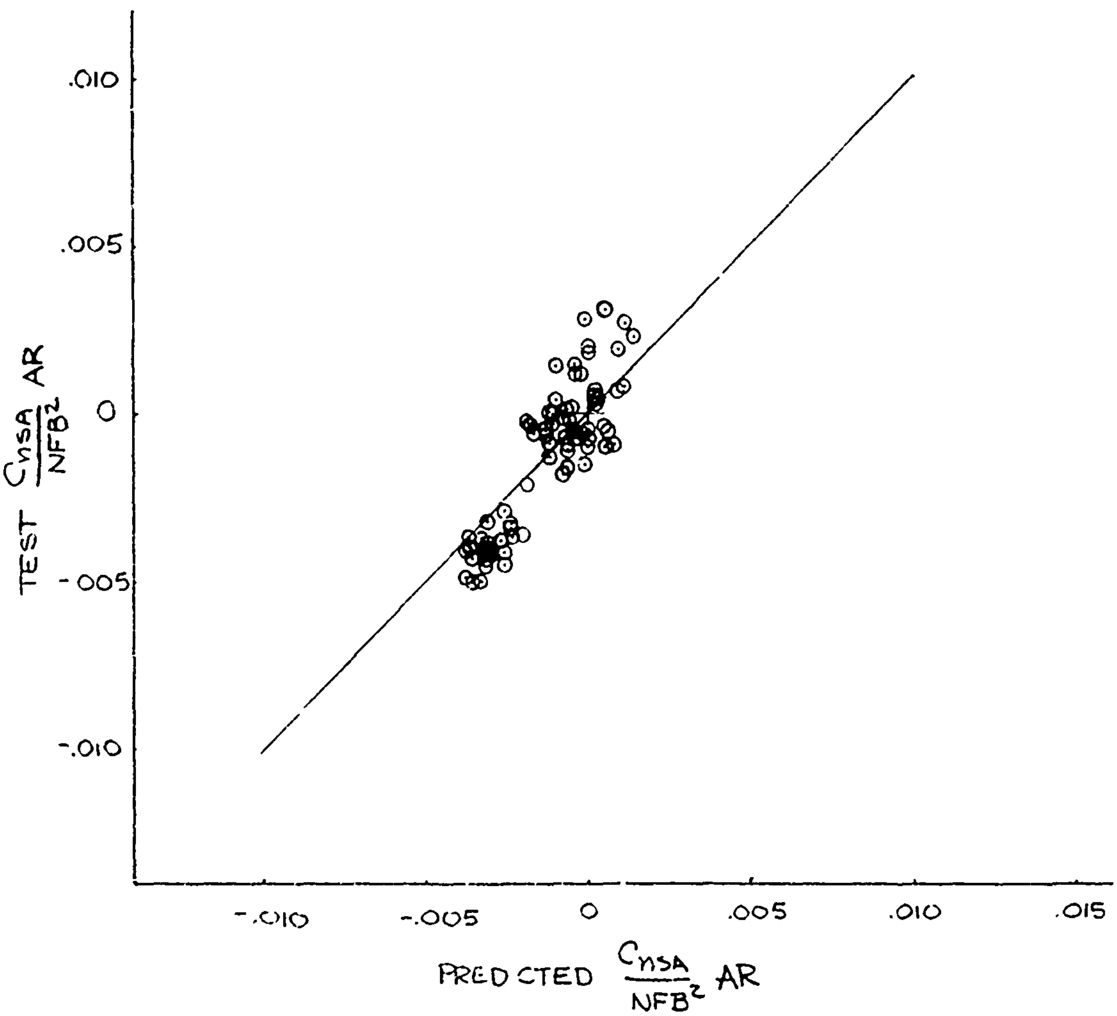
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}$, $\beta = +10^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{n_{SA}}}{NFB^2} AR = -.0354325 + .0000301\ell + .0027539D - .0000904C - .0001556\Lambda X - .0000005 \frac{SA}{FA} \times FSPD - .0022985M^2$$



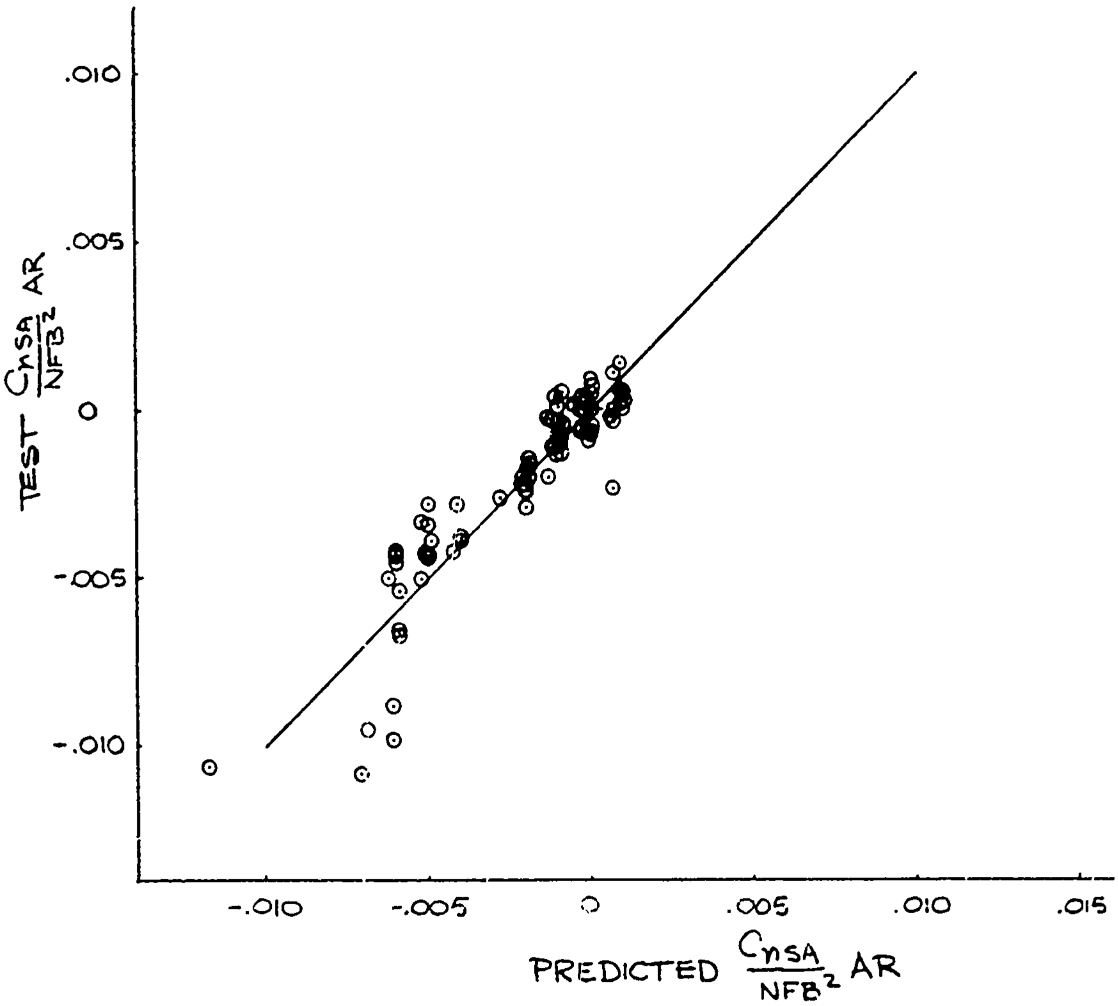
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \beta = -10^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{n_{SA}}}{NFB^2} AR = .0361489 - .0000387\ell - .0021597D + .0000322C + .00005544X - .0000010 \frac{SA}{FA} \times FSPD - .0034869M^2$$



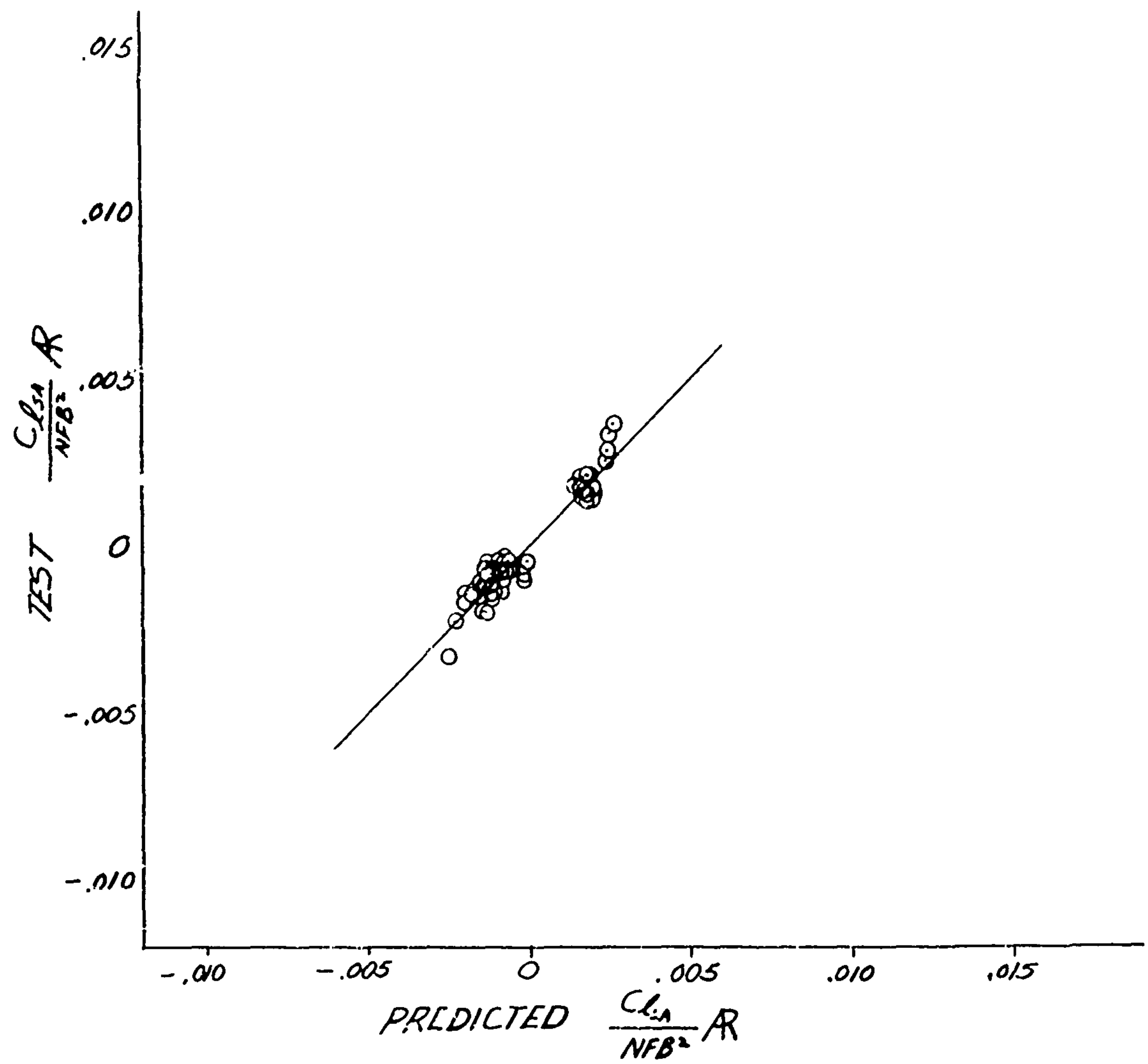
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
ROLLING MOMENT COEFFICIENT

$\alpha_{LOAD} = 16^{\circ},\ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{\ell_{SA}}}{NFB^2} AR = -.0162618 + .0000310\ell + .0009487D - .0000207C - .0000256\Delta X + .0000003\frac{SA}{FA} \times FSPD - .0002054M^2$$



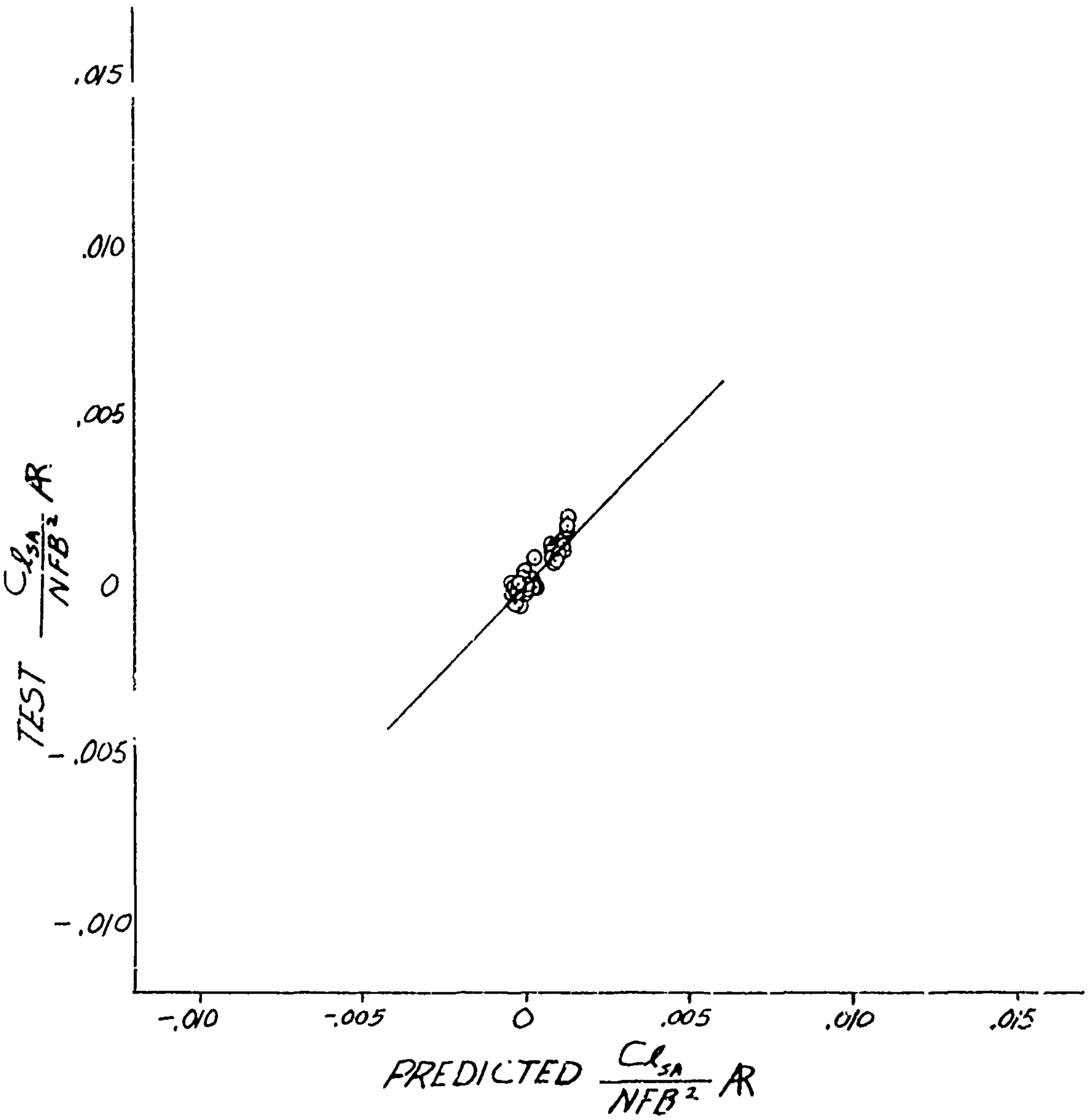
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
ROLLING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^\circ, \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{\ell_{SA}}}{NFB^2} AR = -.0094358 + .0000096\,\ell + .0005843D - .0000089C - .00001529\Delta X + .0000003\,\frac{SA}{FA} \times FSPD + .0000253M^2$$



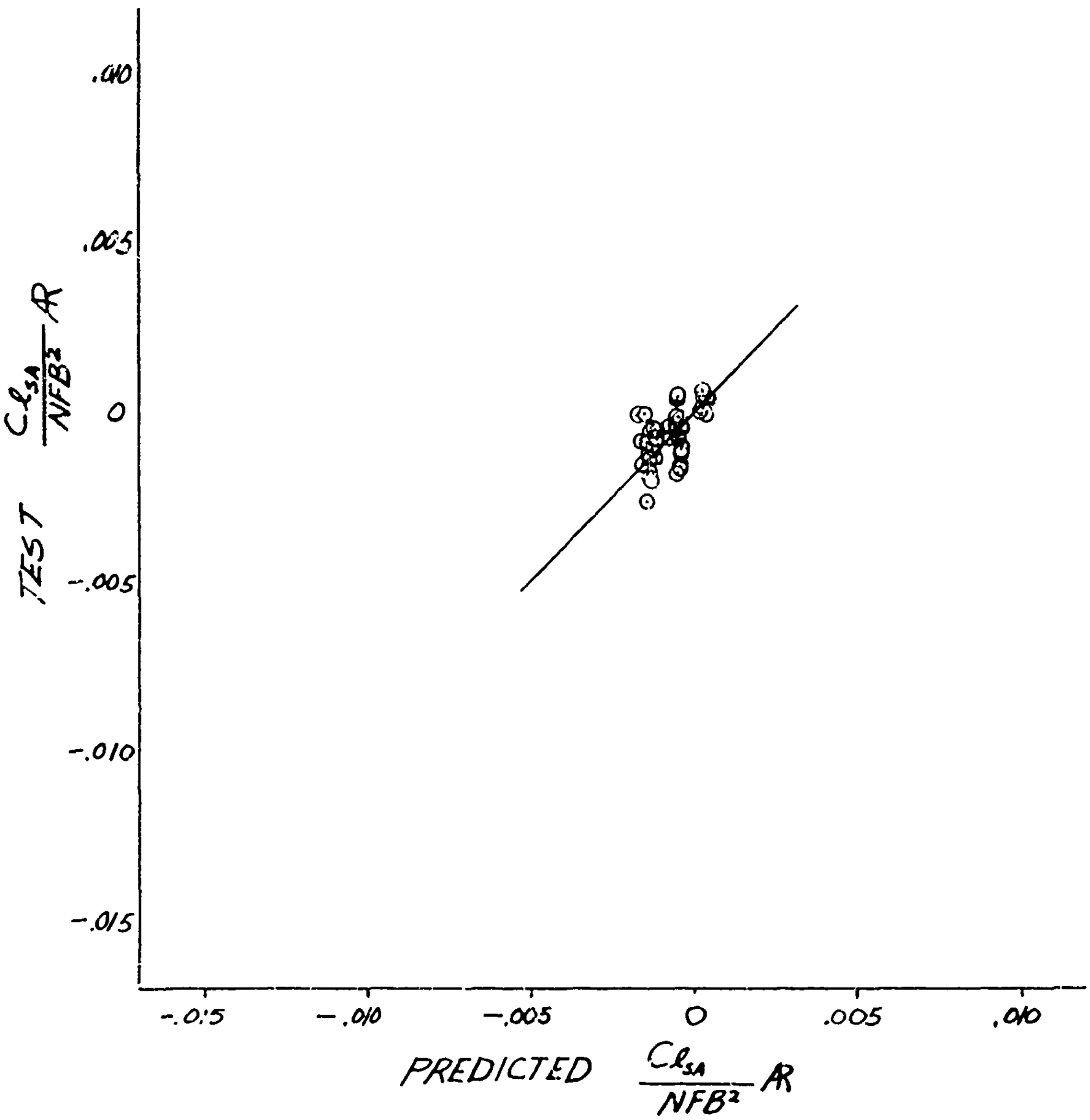
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
ROLLING MOMENT COEFFICIENT

$\alpha_{LOAD} = -4^{\circ},\ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{\ell_{SA}}}{NFB^2} AR = .0350573 + .0000351\ell - .0022957D + .0000026C + .0000083\Delta X - .0000003\ \frac{SA}{FA} \times FSPD - .0002086M^2$$



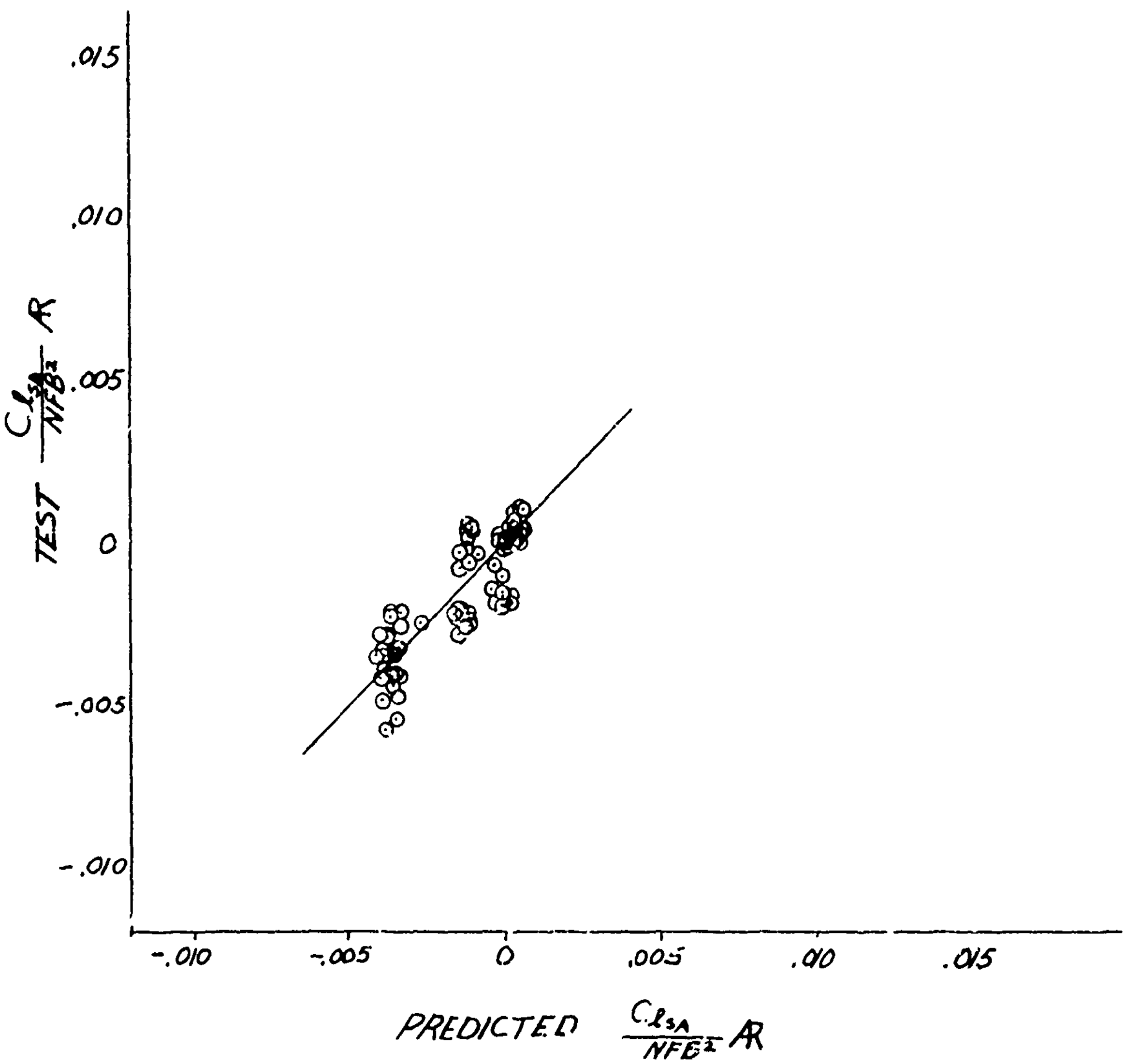
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
ROLLING MOMENT COEFFICIENT

$\alpha_{LOAD} = -9^{\circ},\ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{\ell_{SA}}}{NFB^2} AR = .0684973 + .0000544\ell - .0044968D + .0000075C + .0000265\Delta X - .0000011 \frac{SA}{FA} \times FSPD + .000465M^2$$



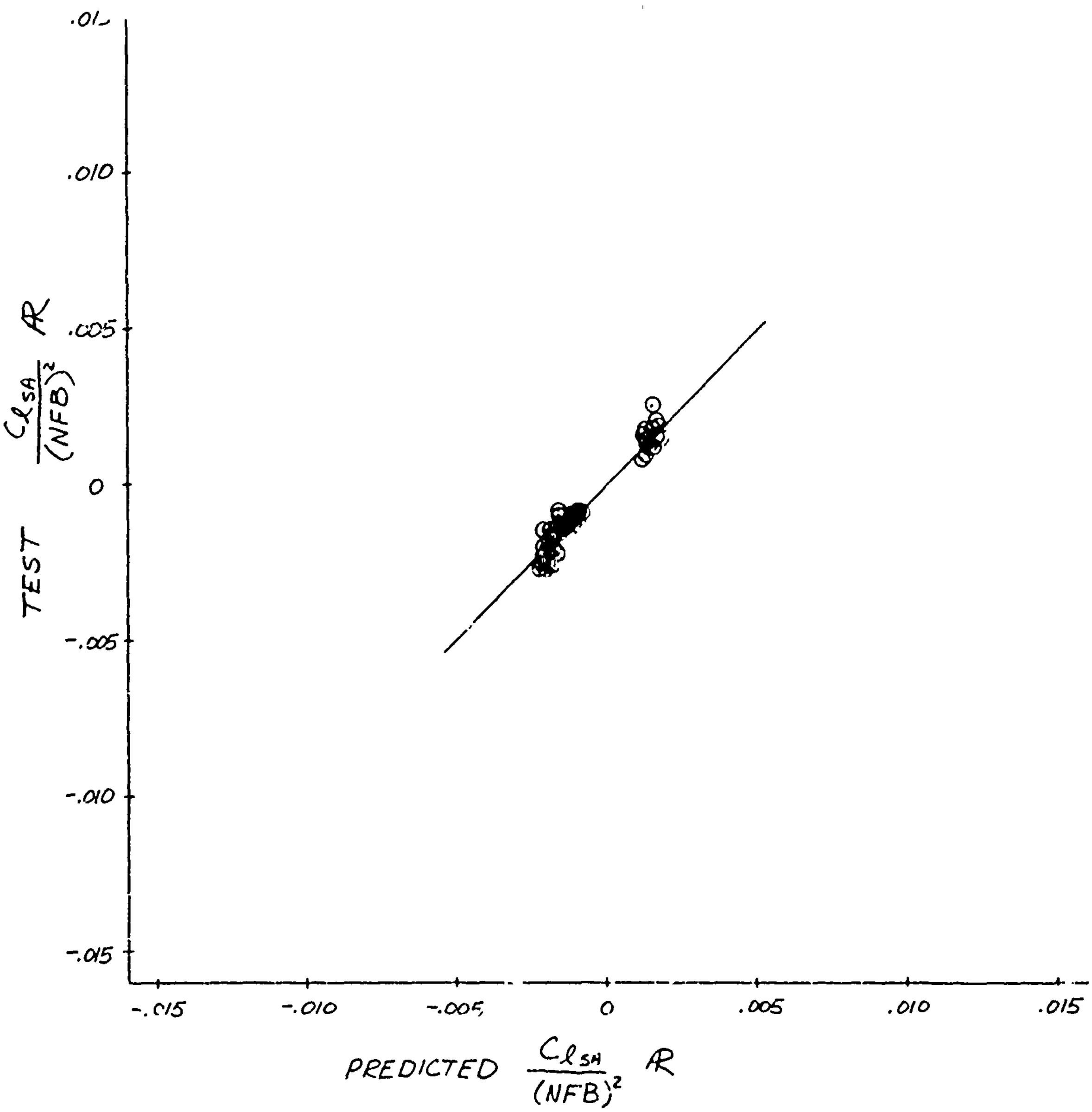
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
ROLLING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^\circ, \ \beta = +10^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{\ell_{SA}}}{NFB^2} AR = -.0095028 + .0000428\ell + .0004747D - .0000202C - .0000237\Delta X - .0000005 \frac{SA}{FA} \times FSPD - .0004463M^2$$



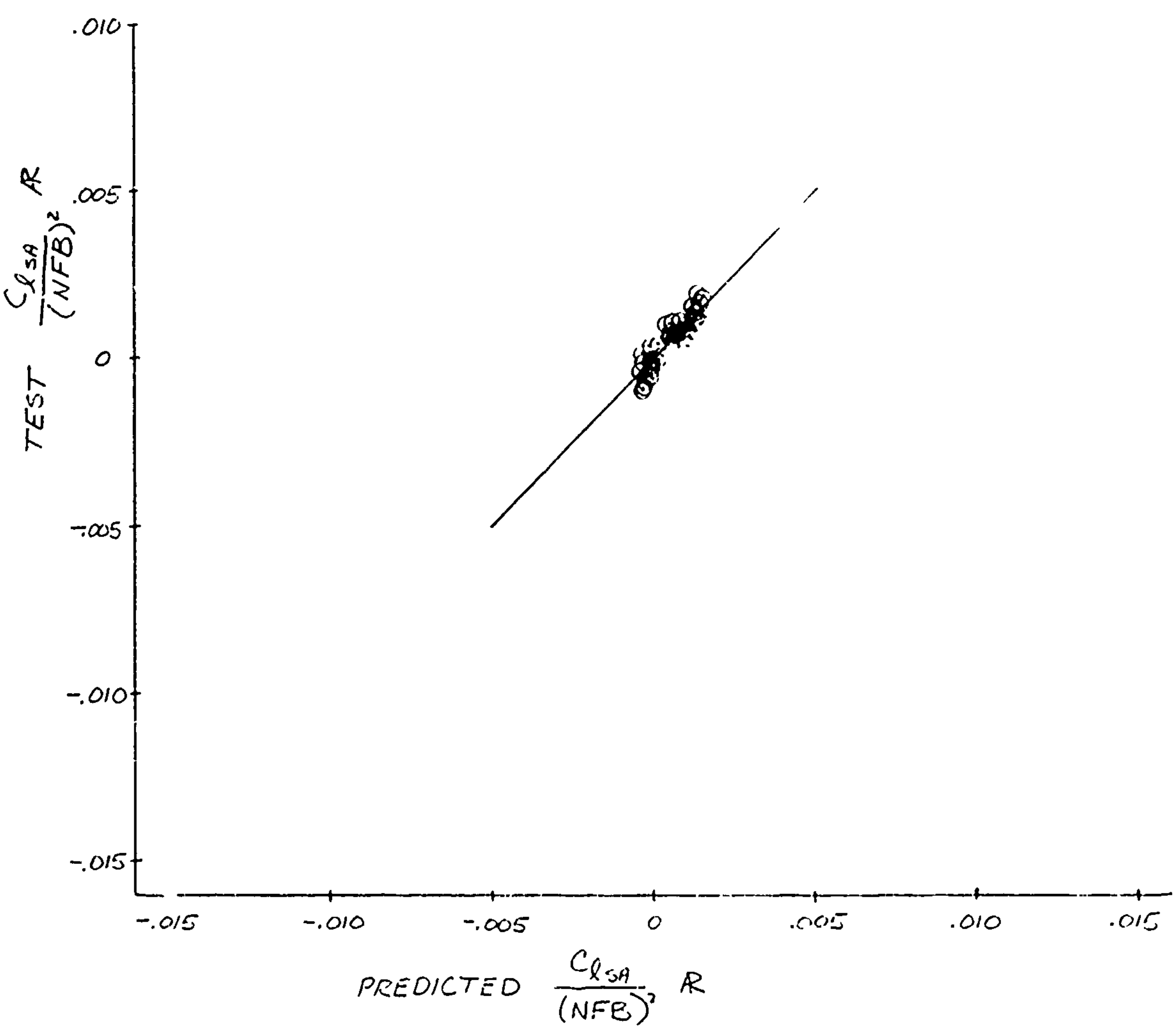
COMPARISON OF TEST AND PREDICTED DATA
FOR CLUSTERED WEAPONS + RACK
Outboard
ROLLING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^{\circ},\ \beta = -10^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

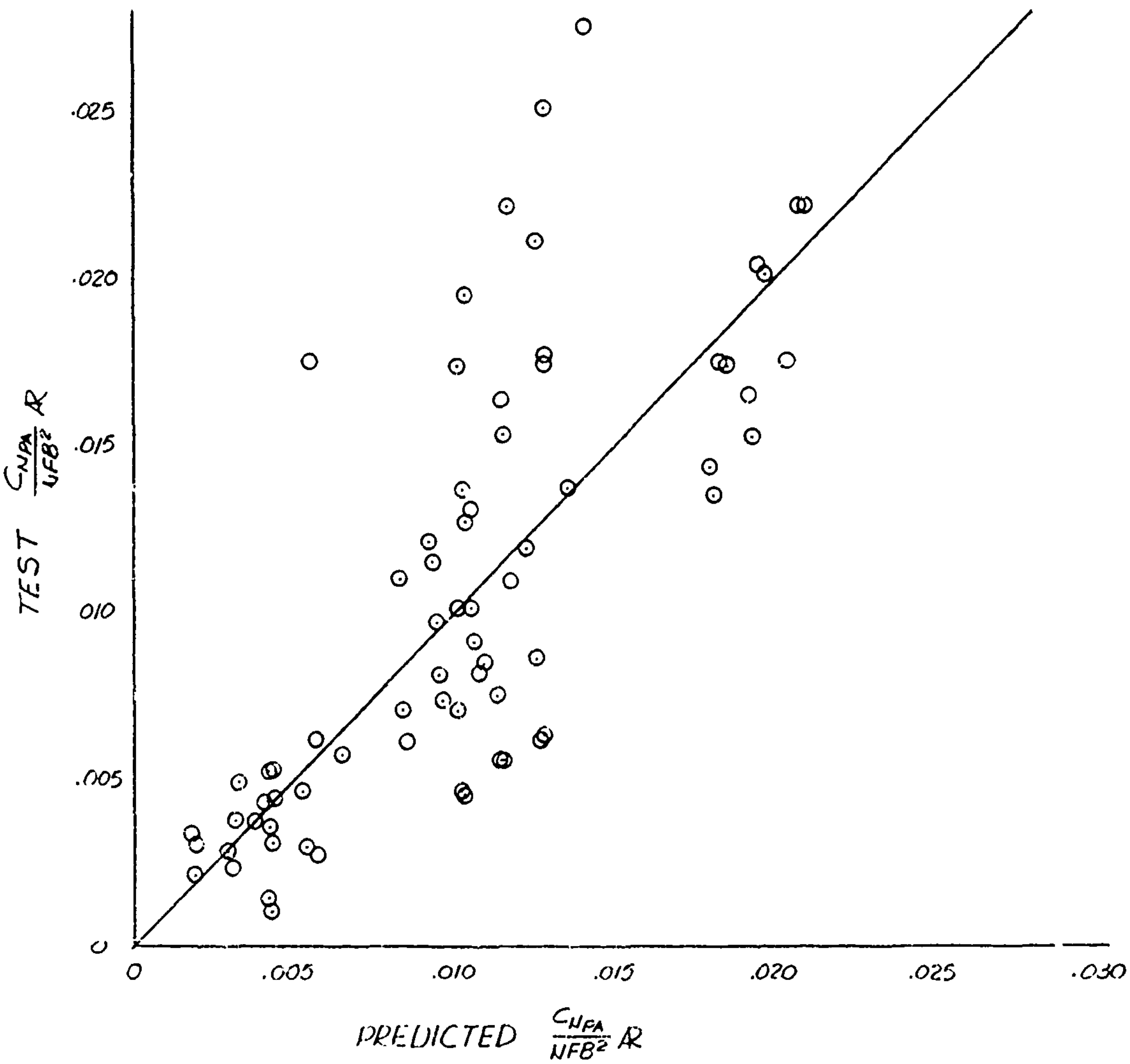
$$\frac{C_{\ell_{SA}}}{NFB^2} AR = .0012699 - .0000114\ell + .0000291D - .0000025C$$
$$-.0000110\Delta X + .0000012 \frac{SA}{FA} \times FSPD + .0000868M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK
INBOARD
NORMAL FORCE COEFFICIENT

$\alpha = 16^{o}$, $\beta = 0$
$M = .6 - .95$
$\Lambda_{LE} = 16^{o} - 72.5^{o}$

$$\frac{C_{N_{P_A}}}{NFB^2} AR = .1754472 + .0004884\ell - .010152D - .0002813C - .0003812\Delta X + .0000035 \frac{PA}{FA} \times FSPD - .0044419M^2$$

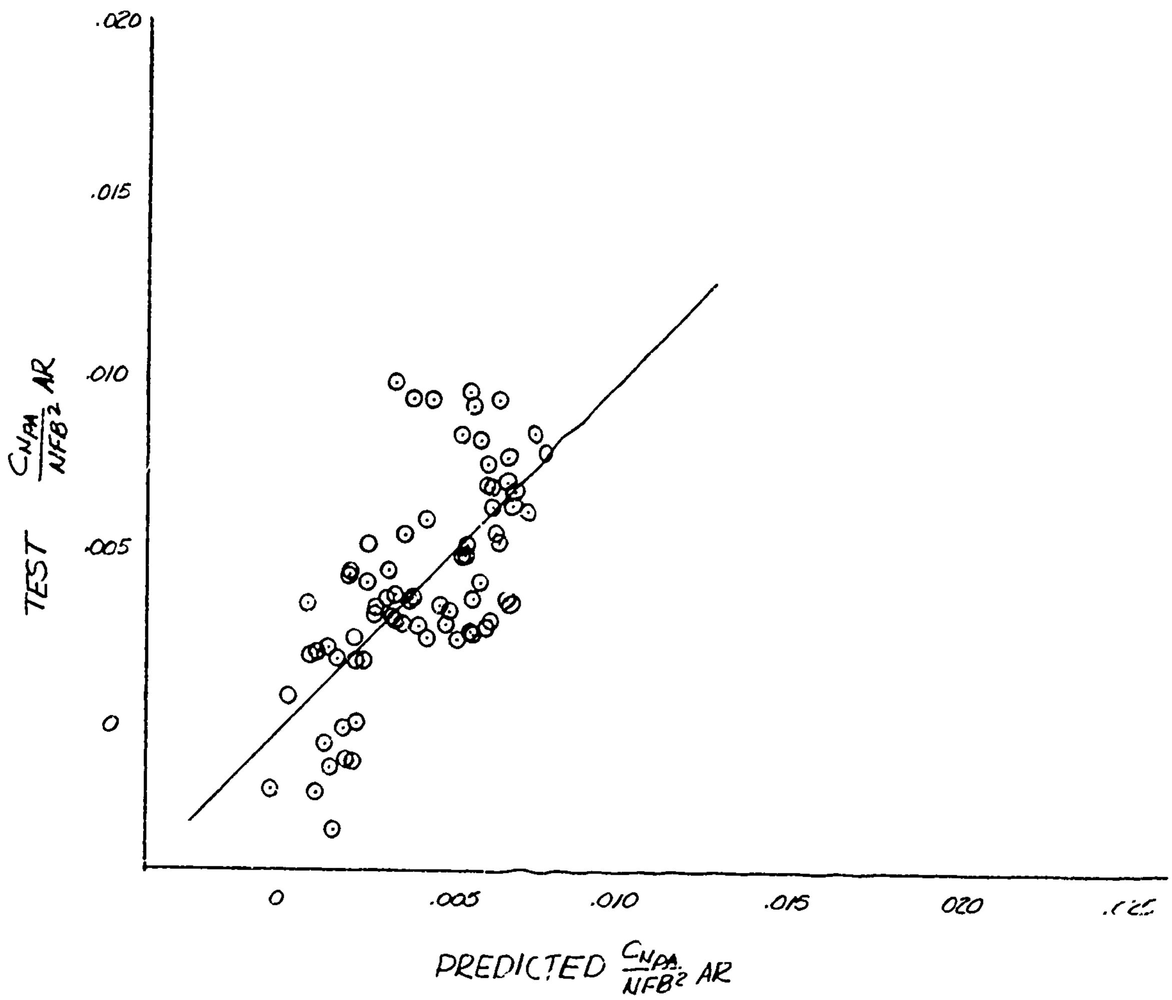


COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK
INBOARD
NORMAL FORCE COEFFICIENT

$\alpha = 6^{\circ}, \ \beta = 0$

$M = .6 - .95, \ \Lambda = 16^{\circ} - 72.5^{\circ}$

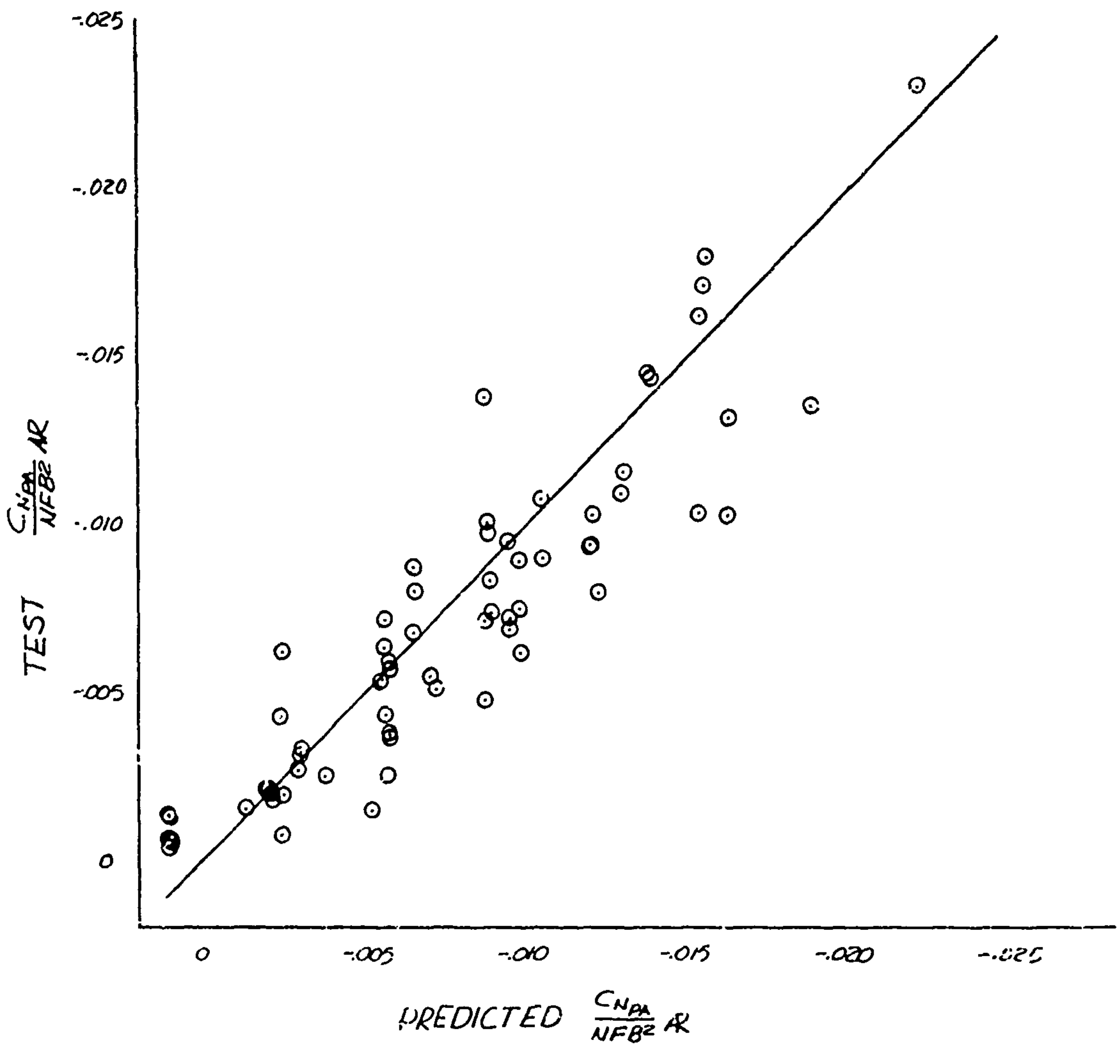
$$\frac{C_{N_{PA}}}{NFB^2} AR = .0497213 + .0002413\ell - .0037999D - .0000022C$$
$$-.0002931\Delta X + .0000058 \frac{PA}{FA} \times FSPD - .0020303M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK
INBOARD
NORMAL FORCE COEFFICIENT

$\alpha = -4^\circ, \quad \beta = 0$
$M = .6 - .95, \Lambda_{LE} = 16^\circ - 72.5^\circ$

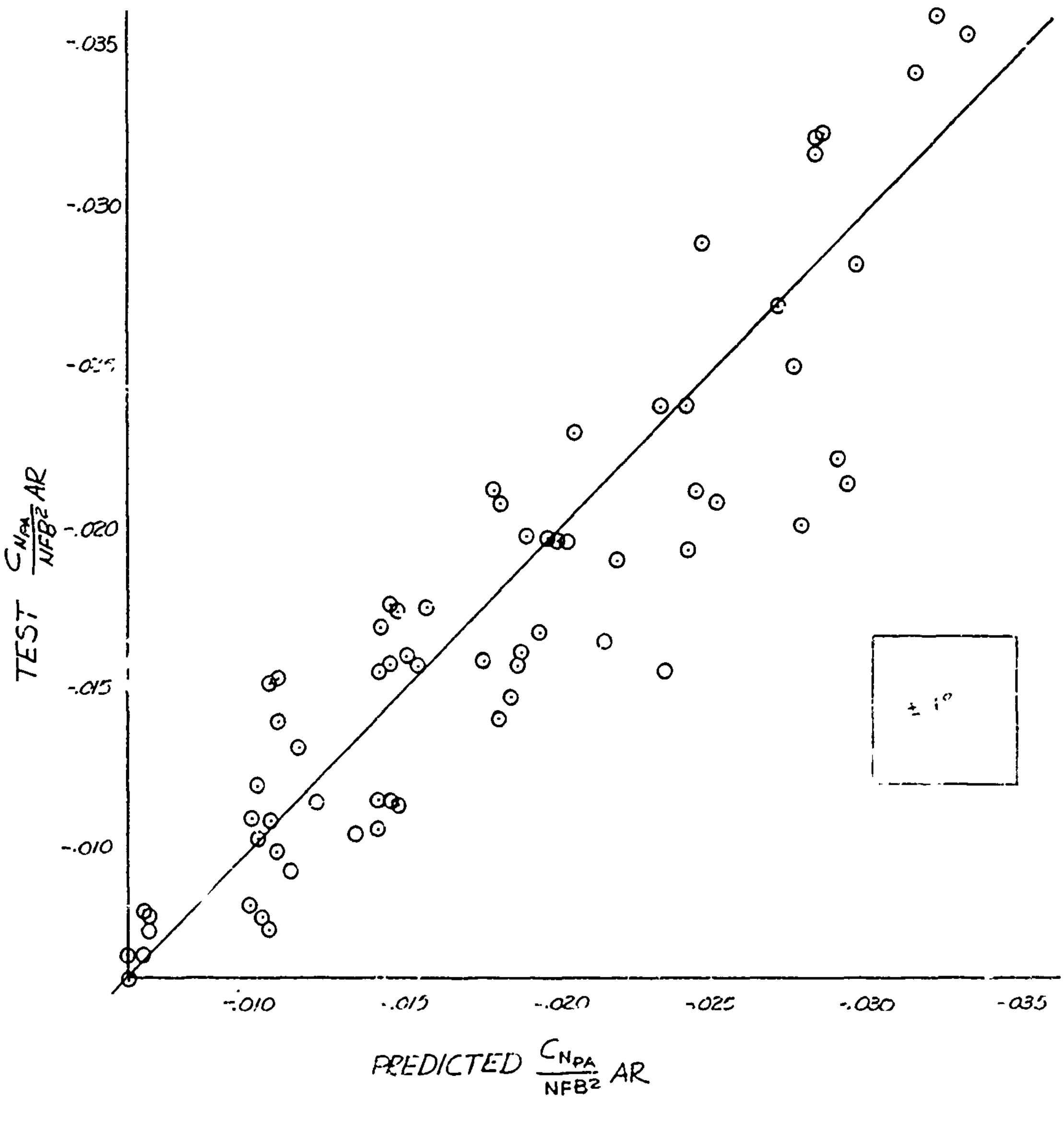
$$\frac{C_{N_{PA}}}{NFB^2} AR = .2082815 + .0005337\ell - .0154469D + .0000623C - .0002162\Delta X - .0000011 \frac{PA}{FA} \times FSPD - .0125524M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK
INBOARD
NORMAL FORCE COEFFICIENT

$\alpha = +9,\ \beta = 0$
$M = .6 - .95,\ \Lambda_{LE} = 16^\circ - 72.5^\circ$

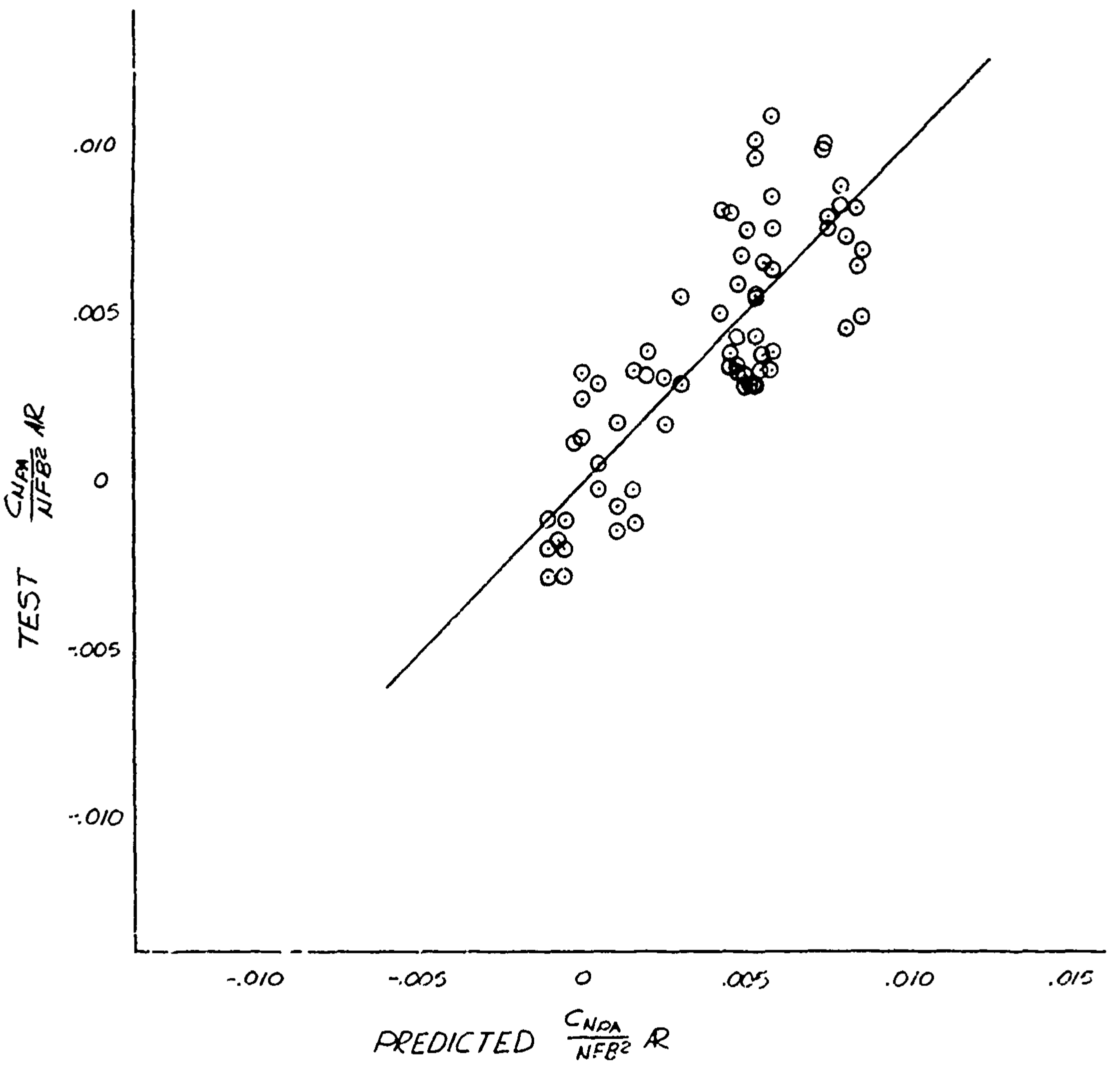
$$\frac{C_{N_{PA}}}{NFB^2}\,AR = .2974829 + .0006\overset{6}{\underset{\wedge}{7}}8\ell - .0209530D - .0000649C$$
$$-.0001772\Delta X - .0000110\,\frac{PA}{FA} \times FSPD - .0148355M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK
INBOARD
NORMAL FORCE COEFFICIENT

$\alpha = 6^{\circ}, \beta = +10$
$M = .6 - .95, \Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{NP_A}}{NFB2} AR = .1020917 + .0003481\ell - .0063710D - .0001755C - .0002704\Delta X - .0000002 \frac{PA}{FA} \times FSPD + .0019147M^2$$

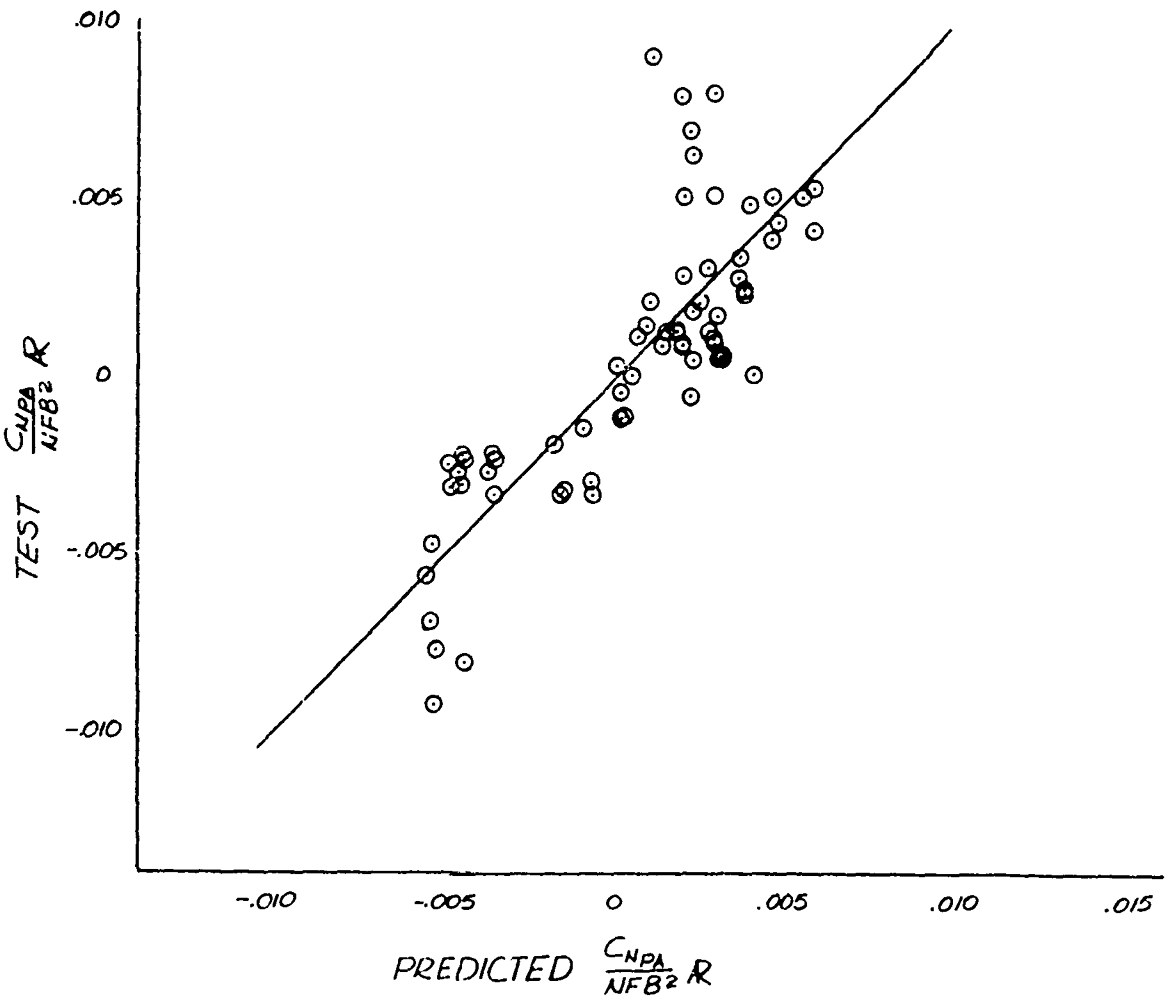


COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK
INBOARD
NORMAL FORCE COEFFICIENT

$\alpha = 6^{\circ}, \quad \beta = -10$

$M = .6 - .95, \Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{N_{PA}}}{NFB^2} AR = .1448328 + .0003940\ell - .0103269D - .0000239C - .0002164\Delta X + .0000045 \frac{PA}{FA} \times FSPD - .0033397M^2$$

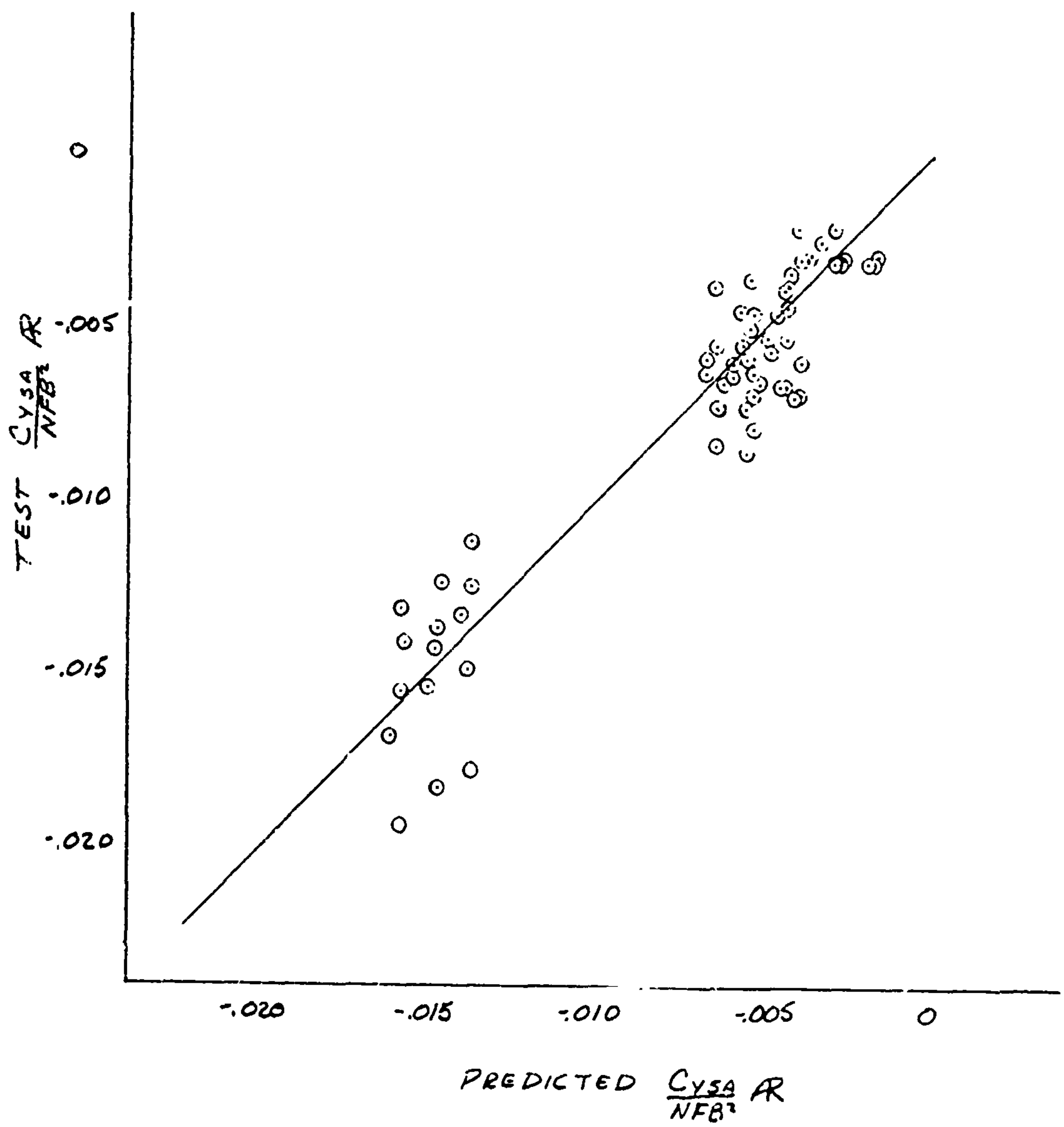


COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK
INBOARD
SIDE FORCE COEFFICIENT

$\alpha = 16^\circ, \quad \beta = 0^\circ$

$M = .6 - .95, \Lambda_{LE} = 16^\circ - 72.5^\circ$

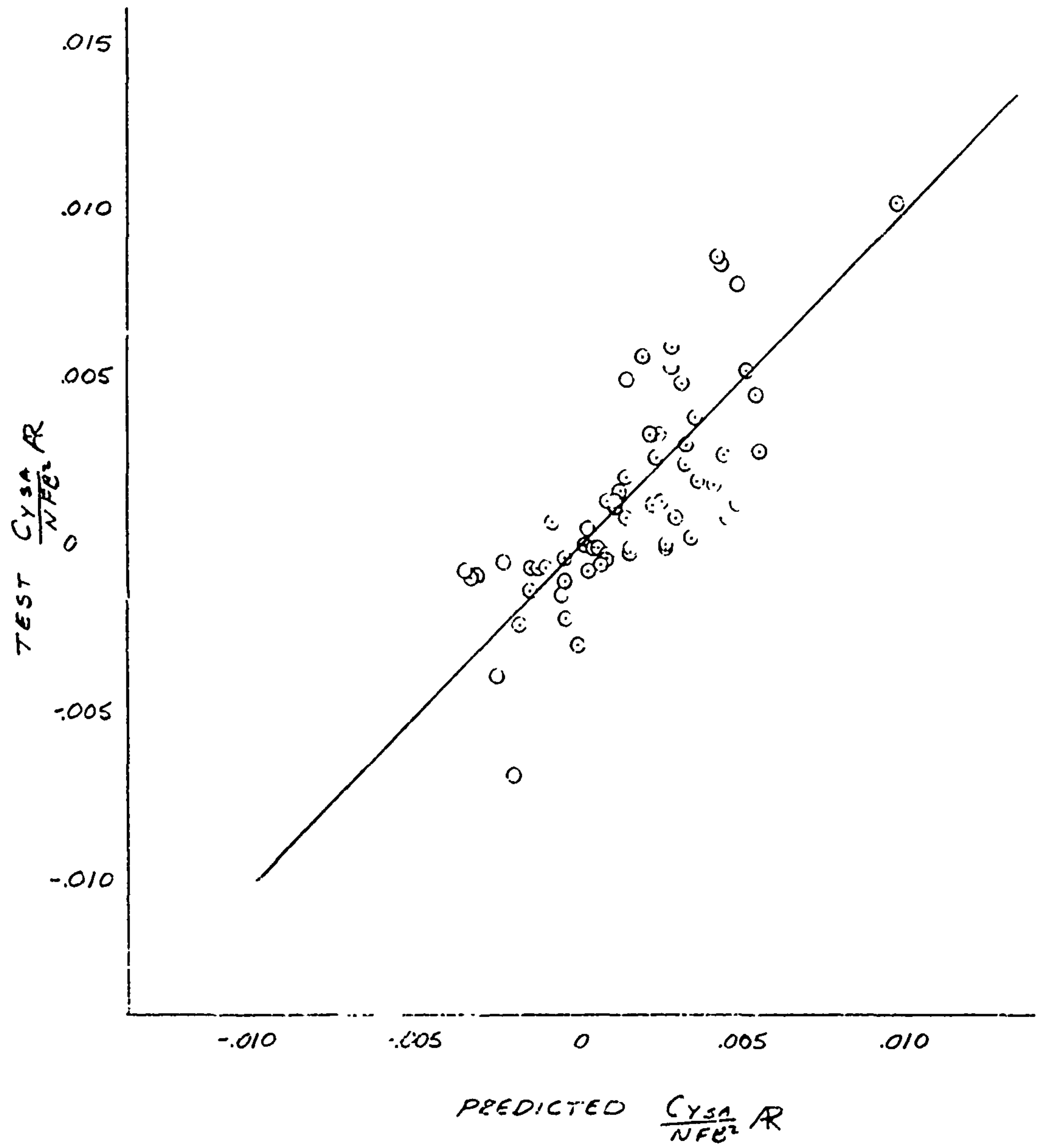
$$\frac{C_{Y_{S_A}}}{NFB^2} AR = .0977910 + .0000270\ell - .0064498D - .0000102C + .0000019\Delta X - .0000011 \frac{SA}{FA} FSPD + .0038091M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK
INBOARD
SIDE FORCE COEFFICIENT

$\alpha = 6^\circ,\ \beta = 0$
$M = .6 - .95,\ \Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{Y_{SA}}}{NFB^2}\ AR = -.0036643 - .0000444\ell + .0000166D + .0000360C + .0000147\Delta X + .0000010\frac{SA}{FA}\ FSPD + .0073938M^2$$

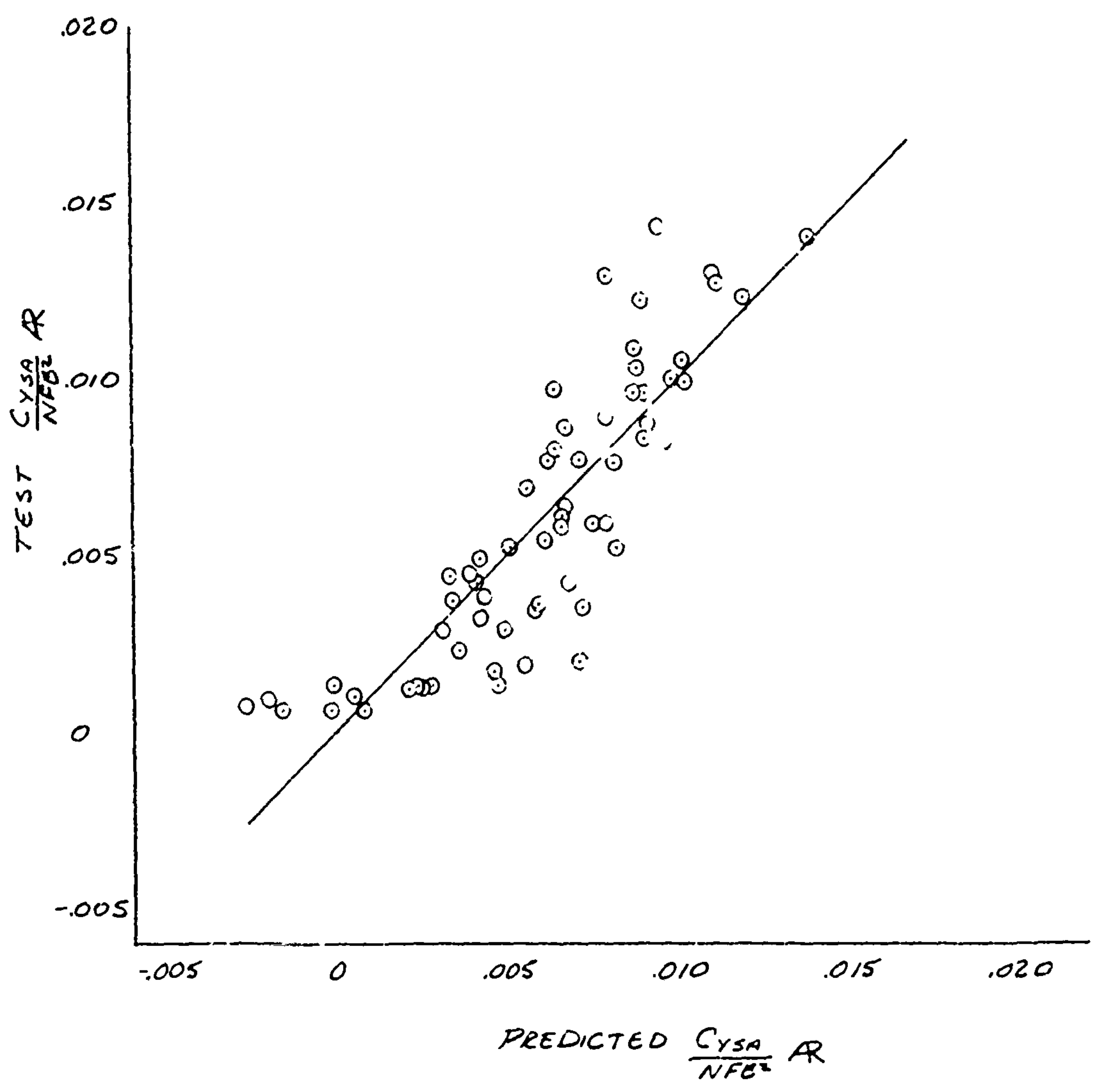


COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK
INBOARD
SIDE FORCE COEFFICIENT

$\alpha = -4^\circ, \ \beta = 0^\circ$

$M = .6 - .95, \ \Lambda = 16^\circ - 72.5^\circ$

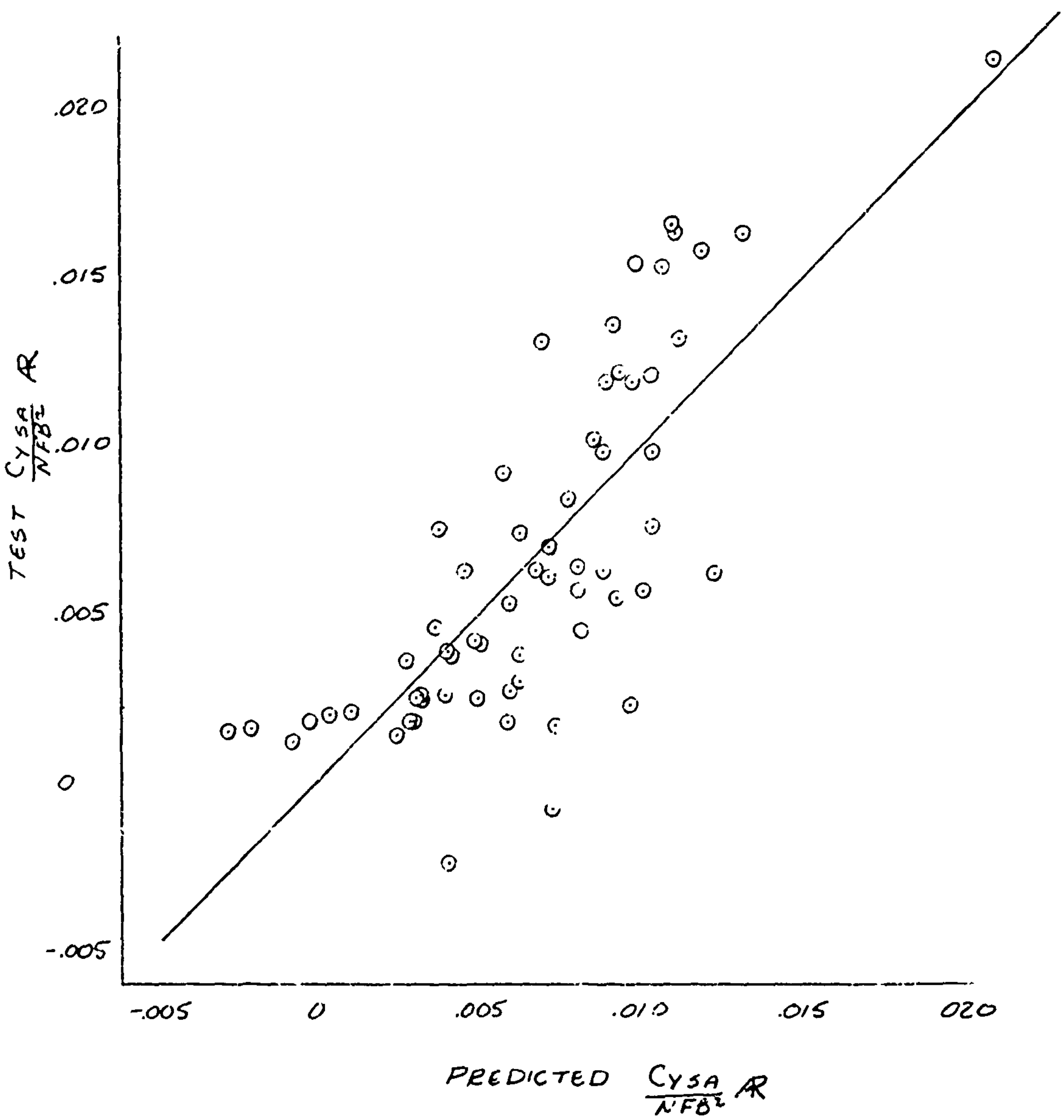
$$\frac{C_{Y_{S_A}}}{NFB^2} AR = -.0516935 - .0000709\ell + .0027760D + .0000912C + .0000058\Delta X + .0000057\frac{SA}{PA} FSPD + .0088161M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK
INBOARD
SIDE FORCE COEFFICIENT

$\alpha = -9^\circ, \ \beta = 0^\circ$
$M = .6 - .95, \ \Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = -.0583186 - .0000854\ell + .0030060D + .0001091C + .0000308\Delta X + .0000083 \frac{SA}{FA} FSPD + .0112094M^2$$

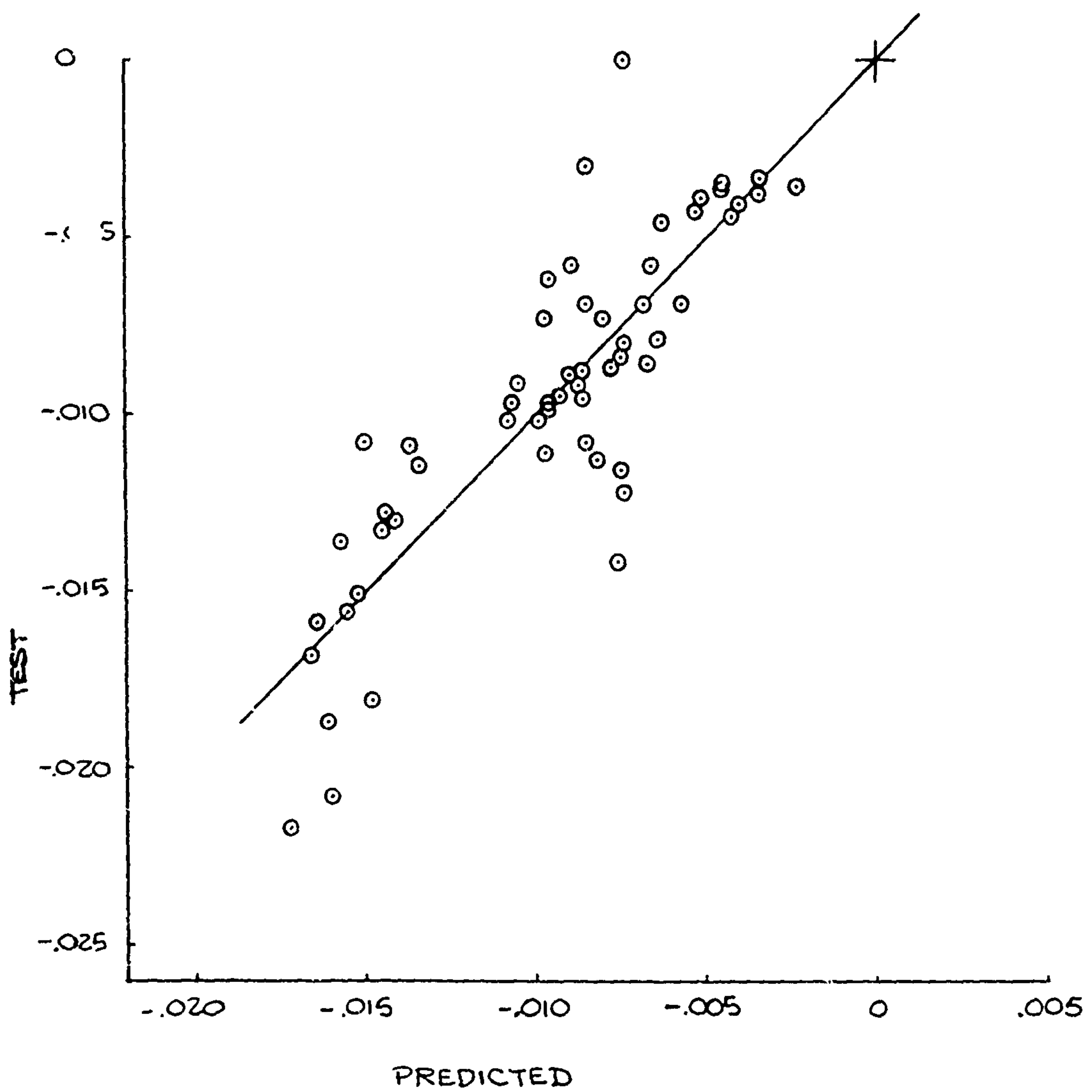


COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK
INBOARD
SIDE FORCE COEFFICIENT

$\alpha = 6^\circ,\ \beta = +10^\circ$

$M = .6 - .95,\ \Lambda_{LE} = 16^\circ - 72.5^\circ$

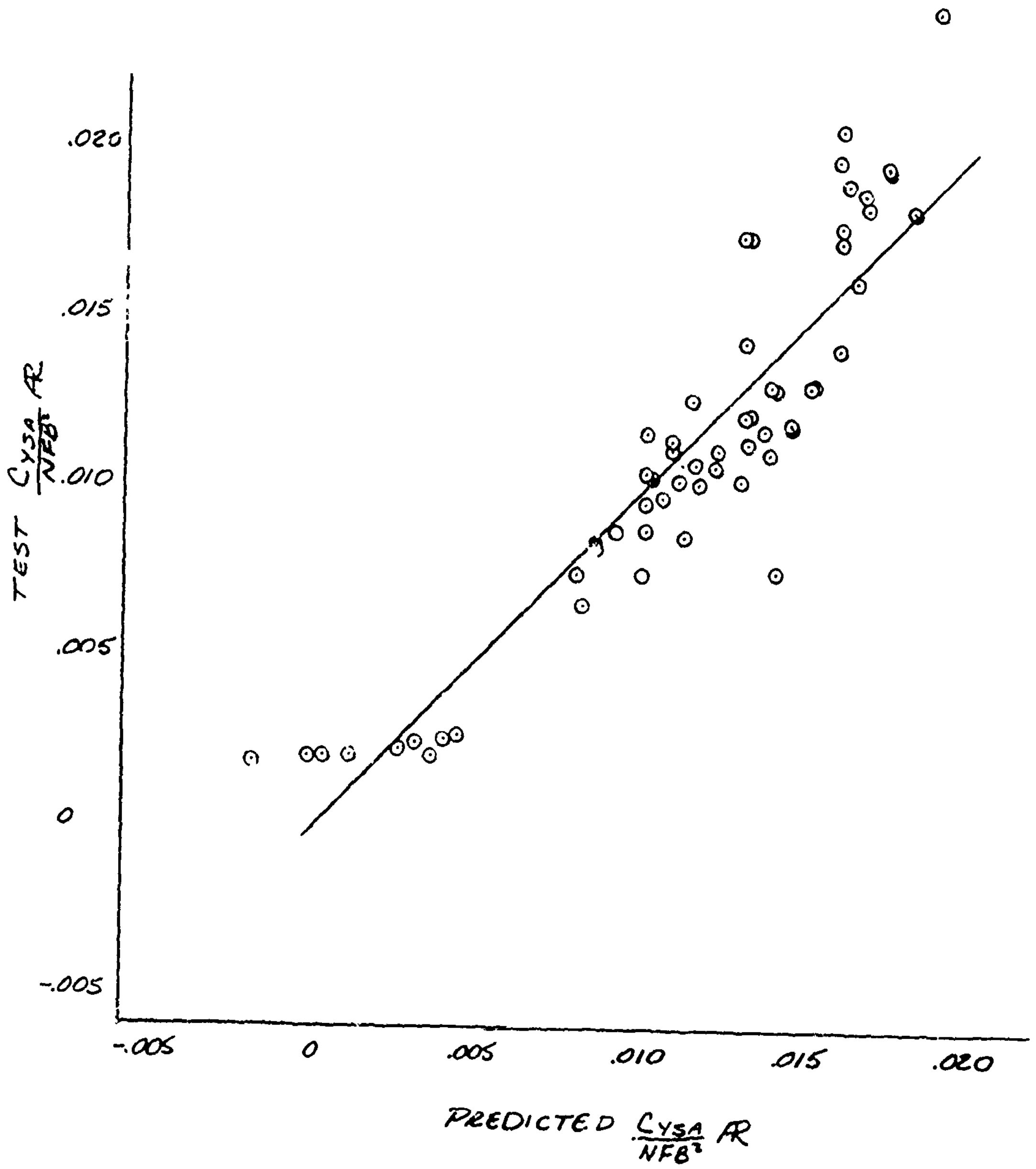
$$\frac{C_{Y_{SA}}}{NFB^2}\ AR = .06887725 + .0001078\ell - .0050757D - .0000373C - .0001503\Delta X + .0000024\frac{SA}{FA}FSPD + .0041811M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK
INBOARD
SIDE FORCE COEFFICIENT

$\alpha = +6, \quad \beta = -10$
$M = .6 - .95, \quad \Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{YSA}}{NFB^2} AR = -.07722975 - .00008827\ell + .00512043D + .00003694C - .00005587\Delta X + .00000406 \frac{SA}{FA} FSPD + .01085569M^2$$

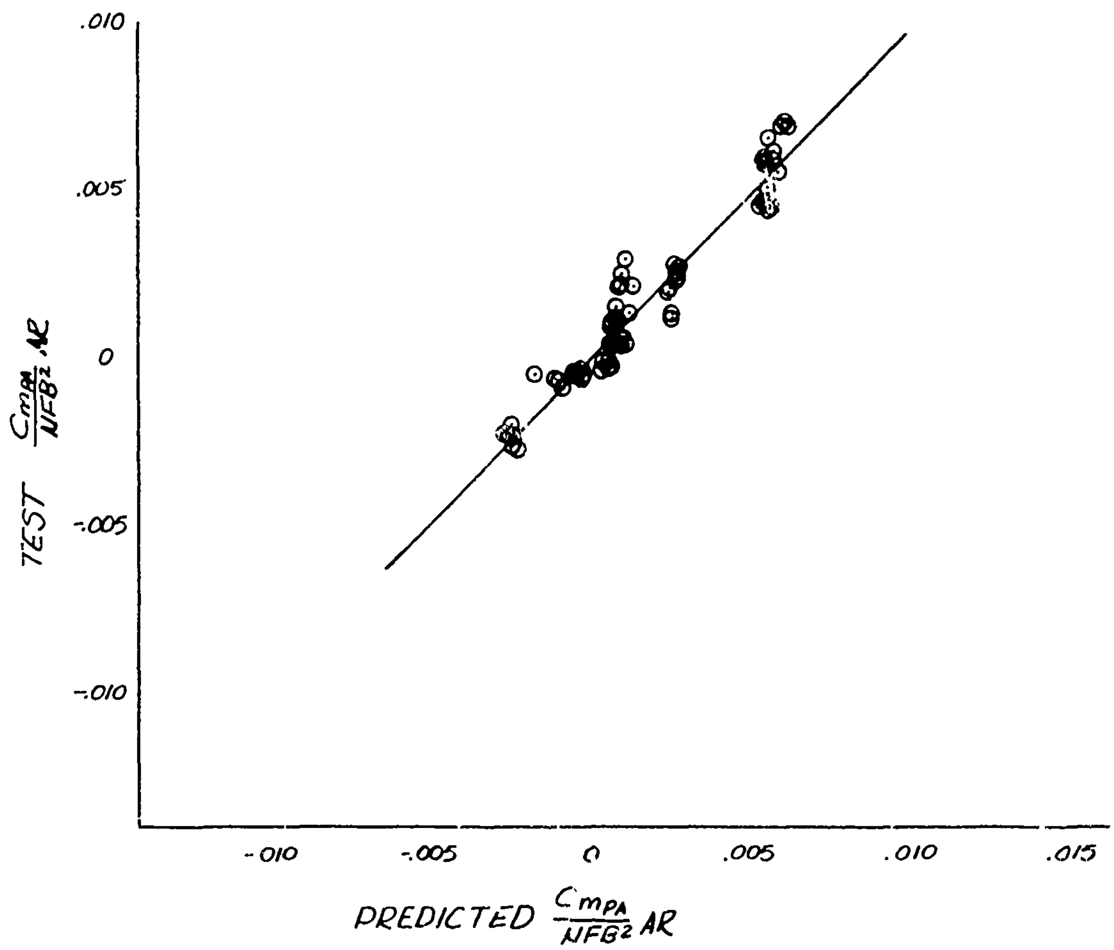


COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK
INBOARD
PITCHING MOMENT COEFFICIENT

$\alpha = 16, \quad \beta = 0$

$M = .6 - .95, \quad \Lambda_{LE} = 16^{o} - 72.5^{o}$

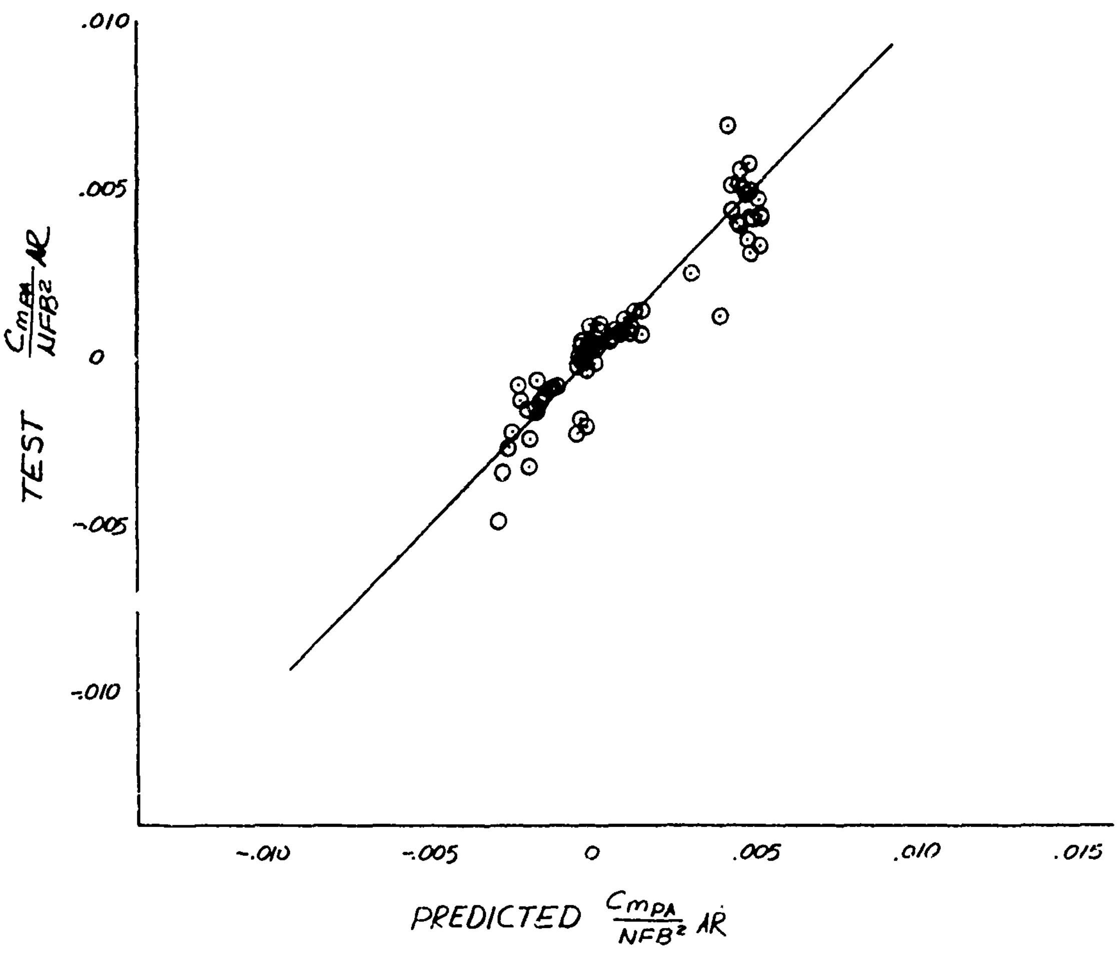
$$\frac{C_{M_{PA}}}{NFB^2} AR = -.0662279 - .0002184\ell + .0053096D - .0000111C + .0000829\Delta X - .0000031 \frac{PA}{FA} \times FSPD - .0005370M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK
INBOARD
PITCHING MOMENT COEFFICIENT

$\alpha = 6, \quad \beta = 0$
$M = .6 - .95, \quad \Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{MP_A}}{NFB^2}\ AR = -.0716873 - .0002011\ell + .0056027D - .0000224C + .0000271\Delta X - .0000018\frac{PA}{FA} \times FSPD - .0010644M^2$$

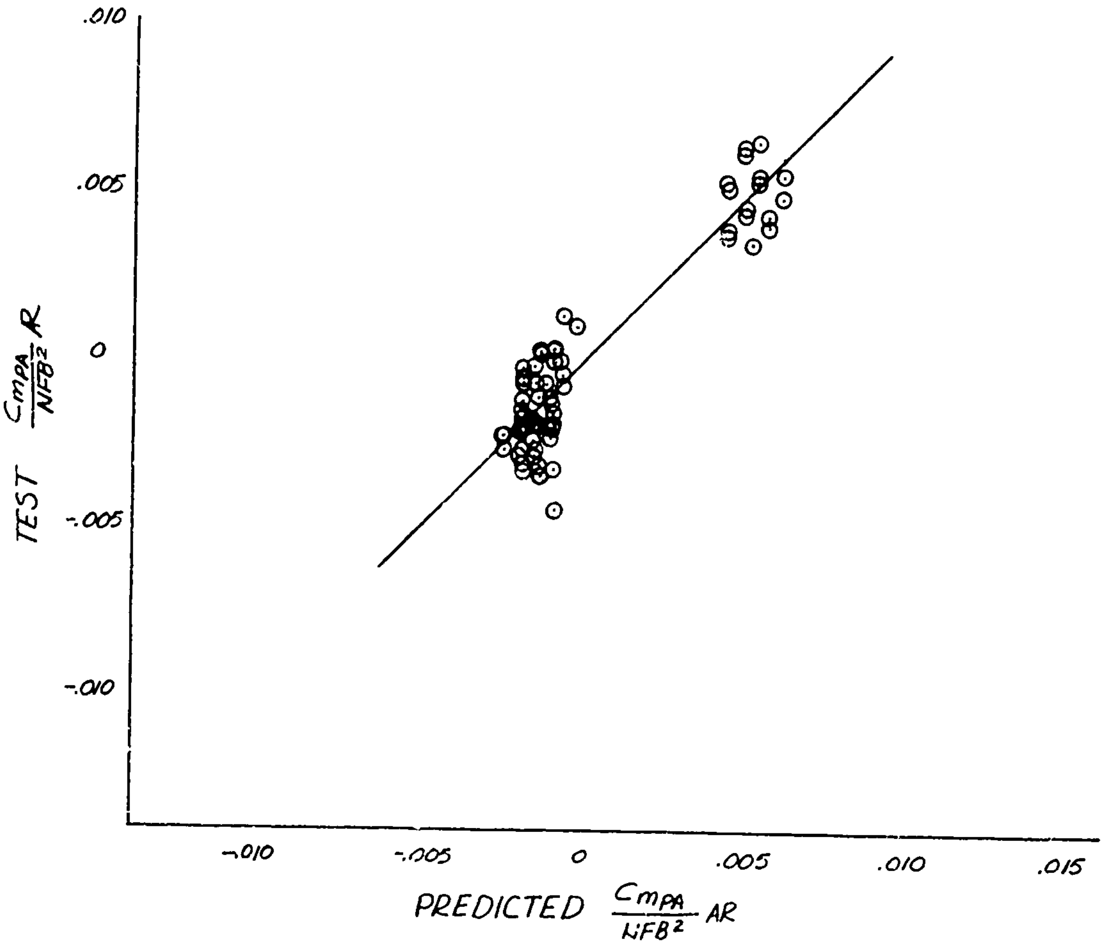


COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK
INBOARD
PITCHING MOMENT COEFFICIENT

$\alpha = -4, \quad \beta = 0$

$M = .6 - .95, \quad \Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{MPA}}{NFB^2} AR = -.1295700 - .00024097\ell + .0092483D - .0000389C - .0000673\Delta X + .0000002\frac{PA}{FA} \times FSPD + .0017587M^2$$

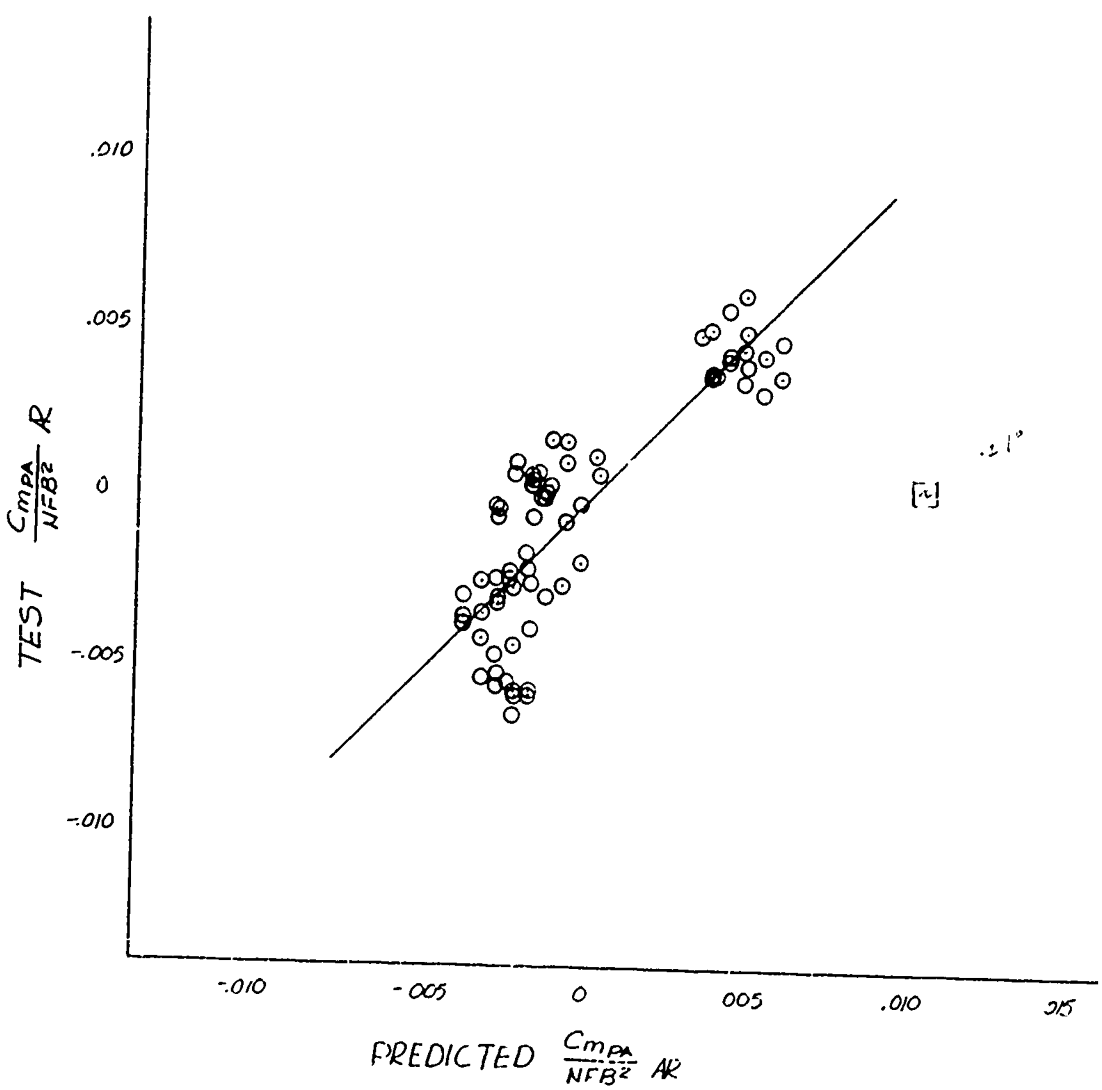


COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK
INBOARD
PITCHING MOMENT COEFFICIENT

$\alpha = -9, \quad \beta = 0$

$M = .6 - .95, \quad \Lambda_{LE} = 16^\circ - 72.5^\circ$

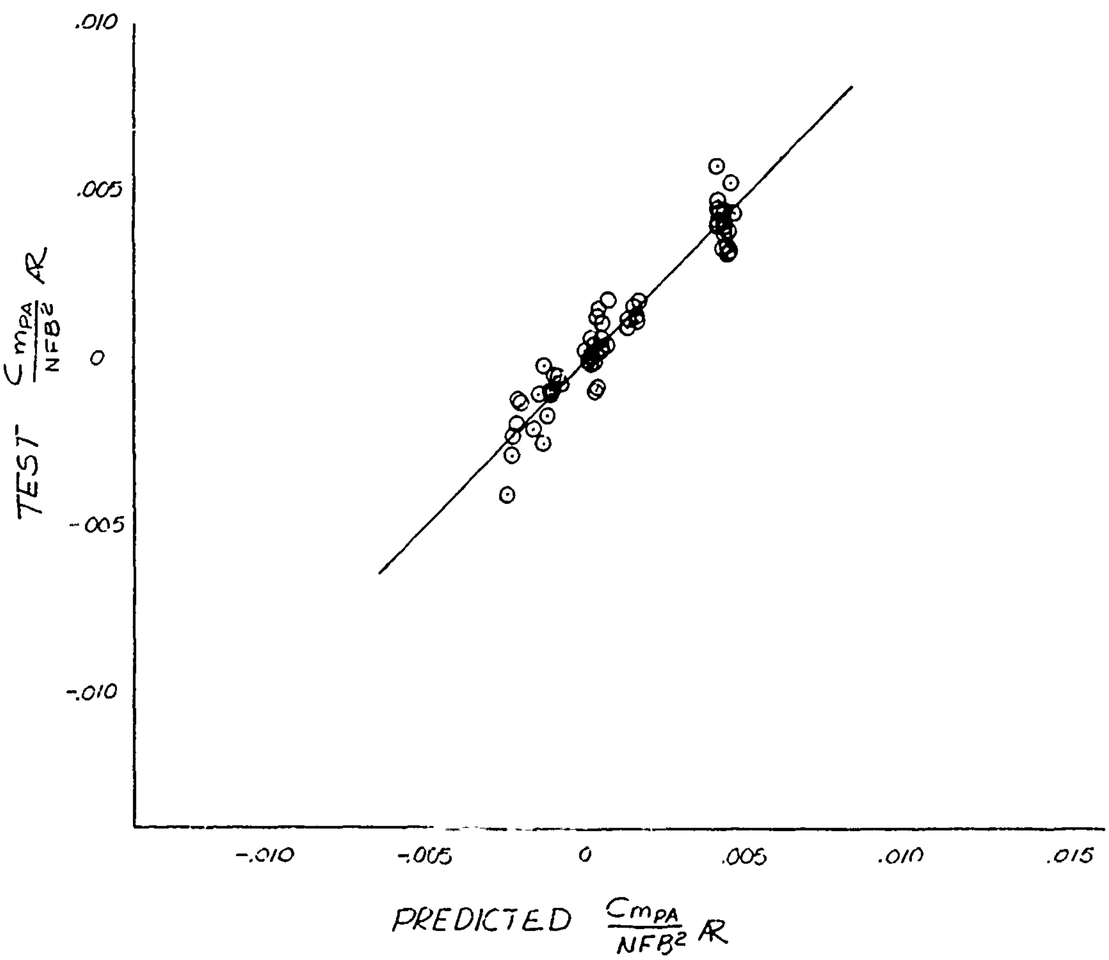
$$\frac{C_{MPA}}{NFB^2}\,AR = -.156075 - .0002286\ell + .0109730D - .0000692C - .0001431\Delta X + .0000007\frac{PA}{FA} \times FSPD + .0018856M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPONS CLUSTER + RACK
INBOARD
PITCHING MOMENT COEFFICIENT

$\alpha = 6, \ \beta = +10$
$M = .6 - .95, \ \Lambda_{LE} = 16^{o} - 72.5^{o}$

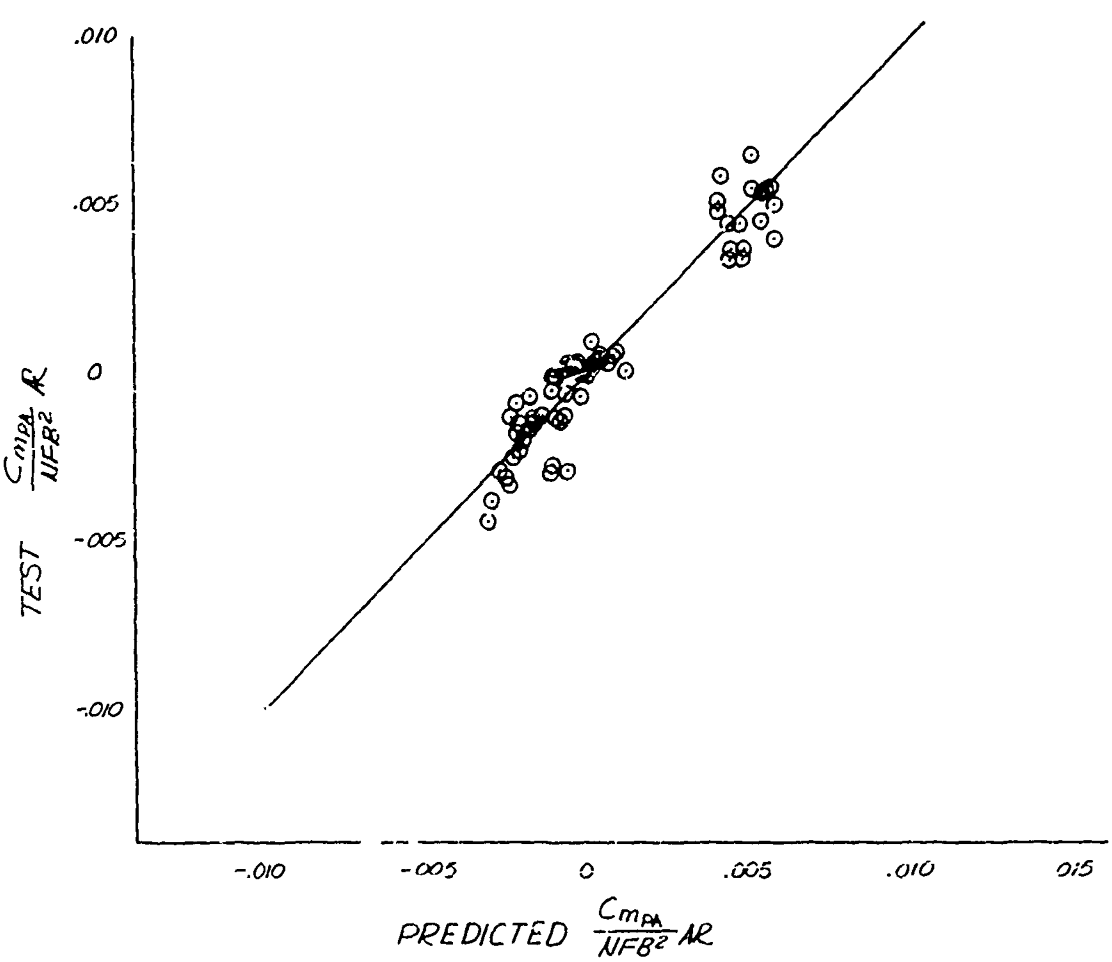
$$\frac{C_{MP_A}}{NFB^2} AR = -.0543135 - .0001672\ell + .0042749D - .0000082C + .0000346\Delta X - .0000016 \frac{PA}{FA} \times TSPD - .0005871M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK
INBOARD
PITCHING MOMENT COEFFICIENT

$\alpha = 6, \quad \beta = -10$
$M = .6 - .95, \Lambda_{LE} = 16^o - 72.5^o$

$$\frac{CM_{PA}}{NFB2} \text{ AR} = -.0310434 - .0002231\ell + .0064130D - .0000425C + .0000331\Delta X - .0000024 \frac{PA}{FA} \times FSPD - .0013519M^2$$



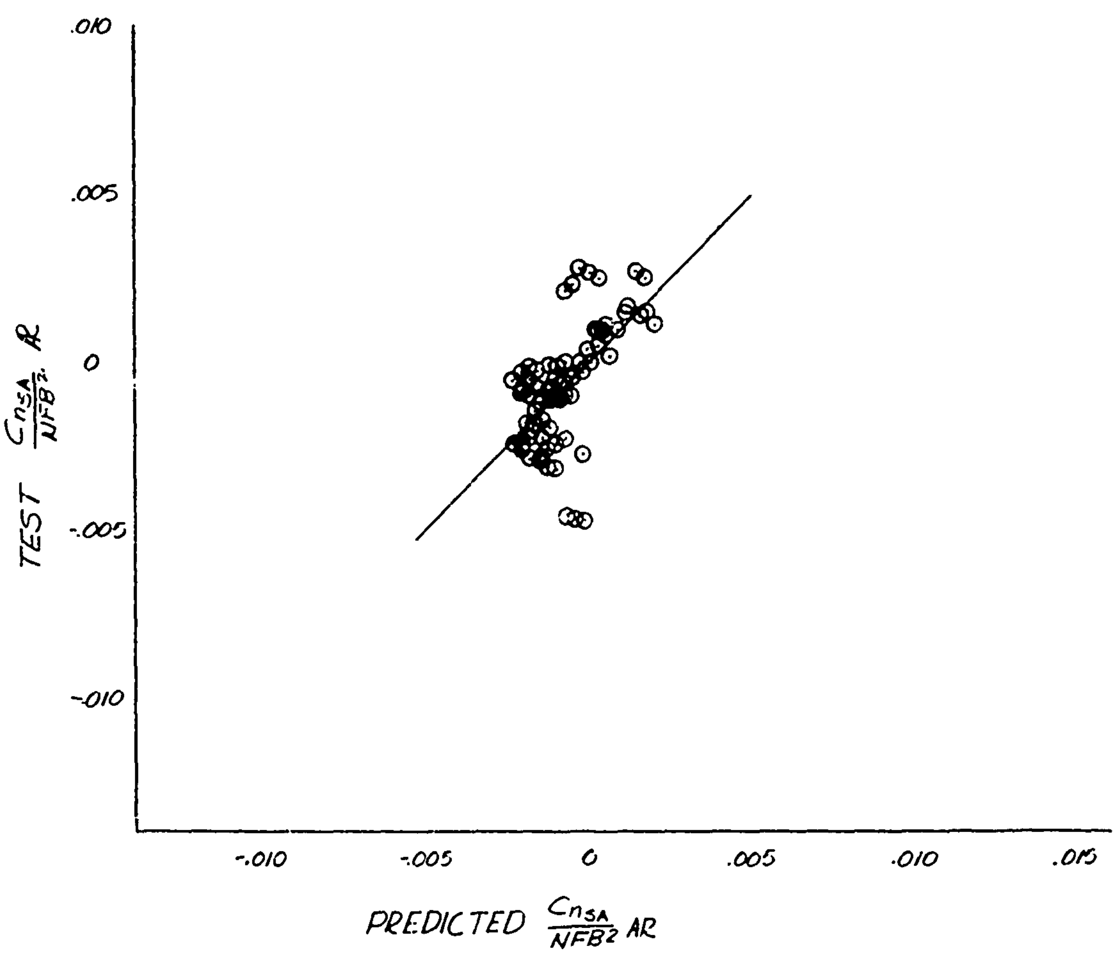
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK
INBOARD
YAWING MOMENT COEFFICIENT

$\alpha = 16^\circ, \quad \beta = 0^\circ$

$M_N = .6 - .95$

$\Lambda = 16^\circ - 72.5^\circ$

$$\frac{C_{NSA}}{NFB^2} AR = -.0029212 - .0000175\ell + .0020040D - .0002230C + .0000024\Delta X - .0000173 \frac{SA}{FA} \times FSPD - .0009609M^2$$



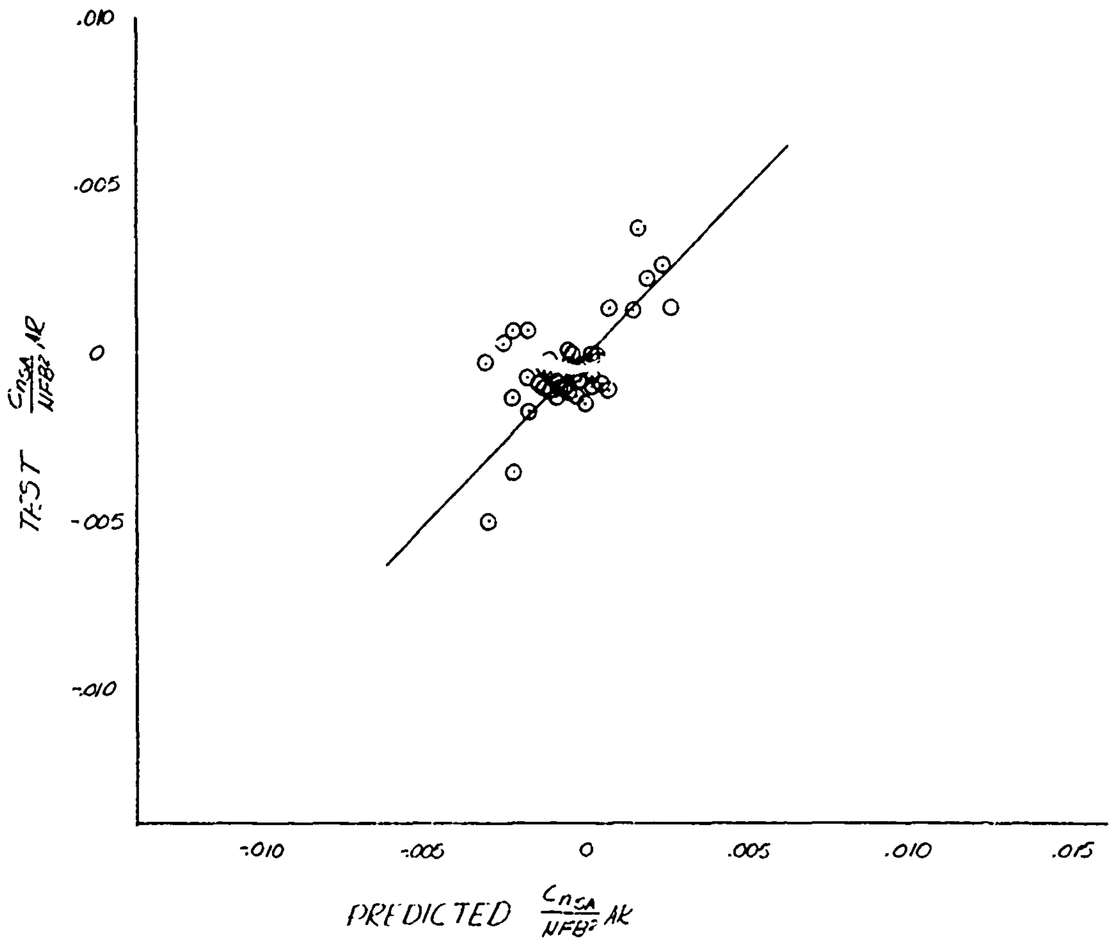
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK
INBOARD
YAWING MOMENT COEFFICIENT

$\alpha = 6°, \quad \beta = 0°$

MN = .6 - .95

$\Lambda_{LE} = 16° - 72.5°$

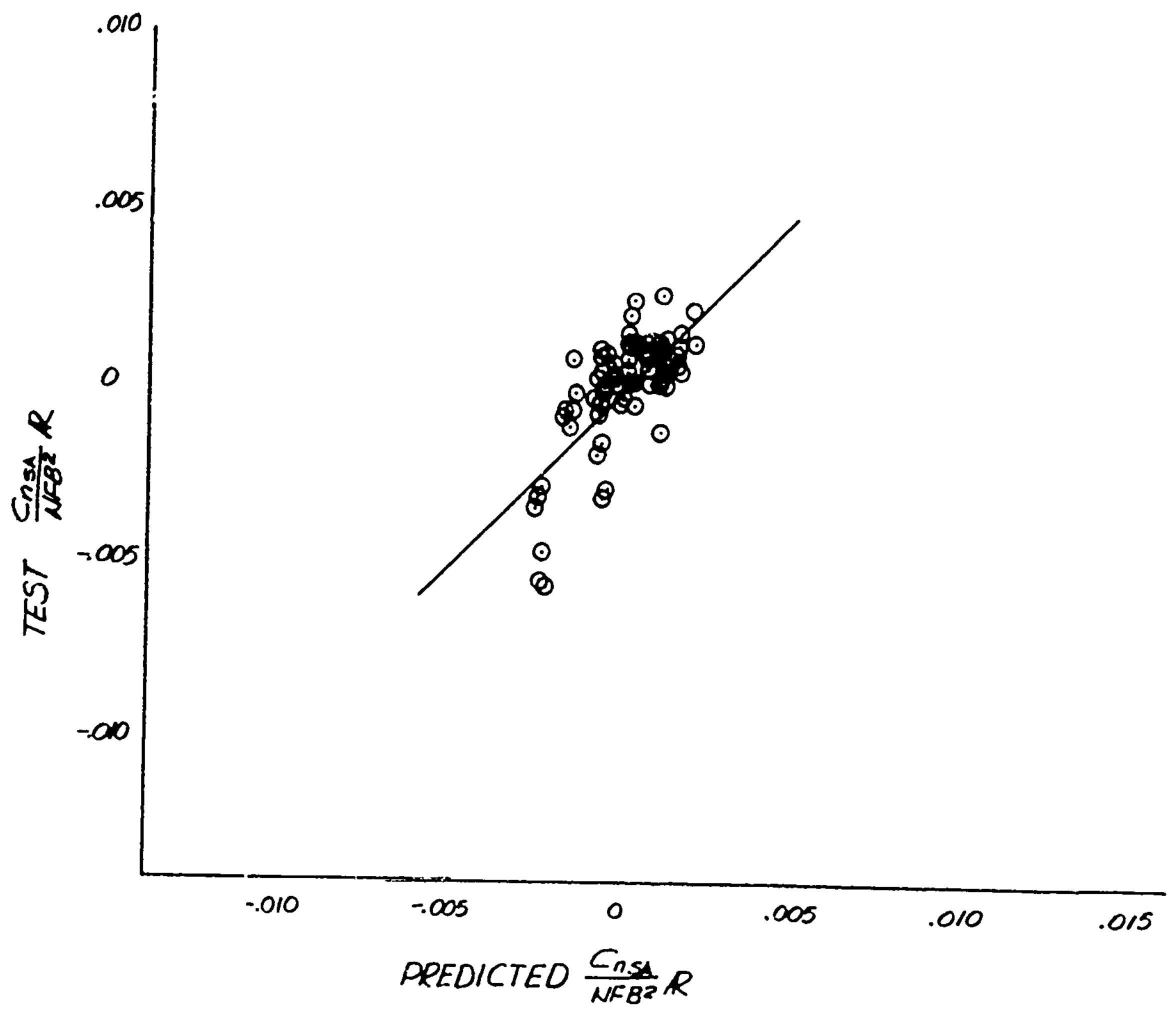
$$\frac{C_{N_{SA}}}{NFB^2} AR = .0362250 + .0000033\ell - .005486D - .0002002C - .0000041\Delta X - .0000156 \frac{SA}{FA} \times FSPD - .0027752M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK
INBAORD
YAWING MOMENT COEFFICIENT

$\alpha = 4^\circ, \quad \beta = 0^\circ$
$MN = .6 - .95$
$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{NSA}}{NFB^2} \; AR = .0379166 + .0000074\ell - .0017100D - .0000617C + .0000200\Delta X - .0000046\,\frac{SA}{FA} \times FSPD - .0032167M^2$$



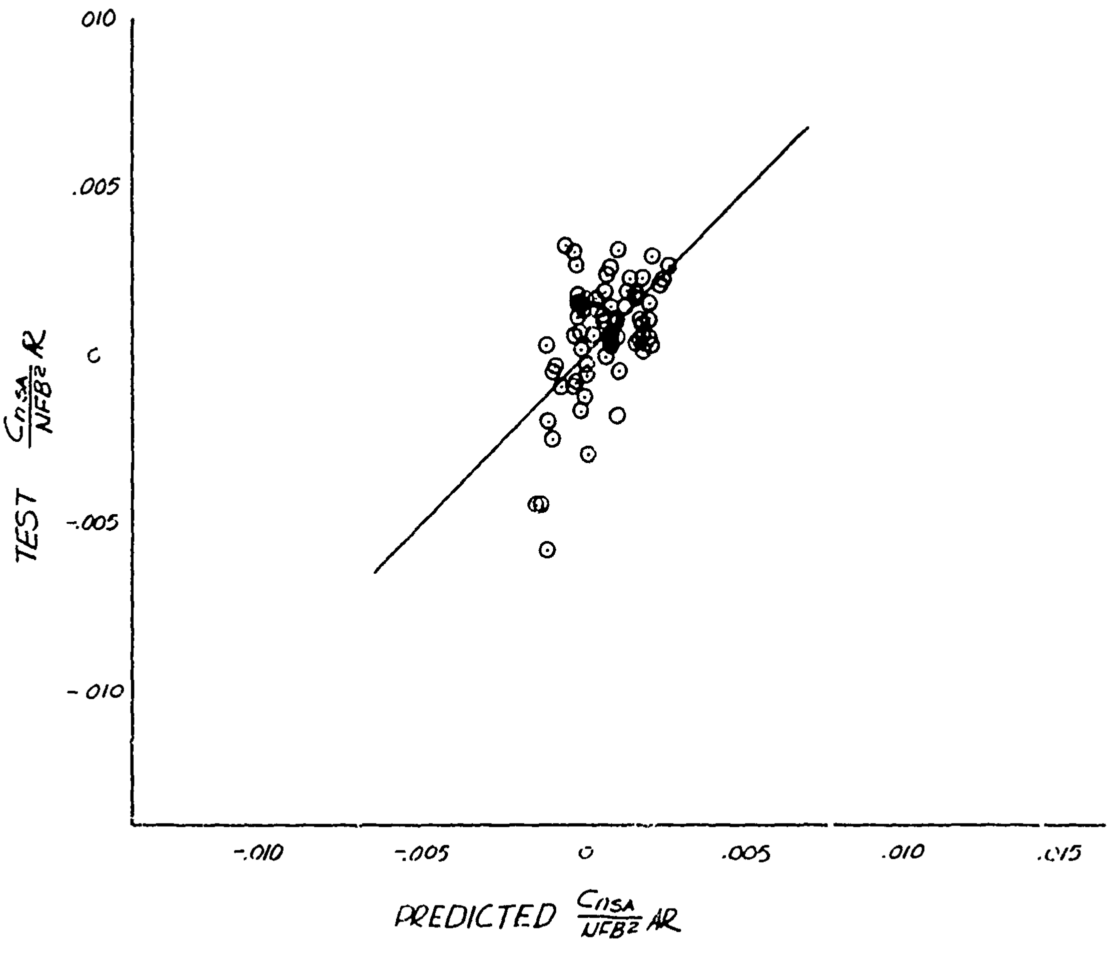
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK
INBOARD
YAWING MOMENT COEFFICIENT

$\alpha = -9^\circ, \quad \beta = 0^\circ$

$MN = .6 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{NS_A}}{NFB^2} AR = .0549715 + .0000415\ell - .002762D - .0000777C + .0000433\Delta X - .0000076 \frac{SA}{FA} \times FSPD - .0035995M^2$$



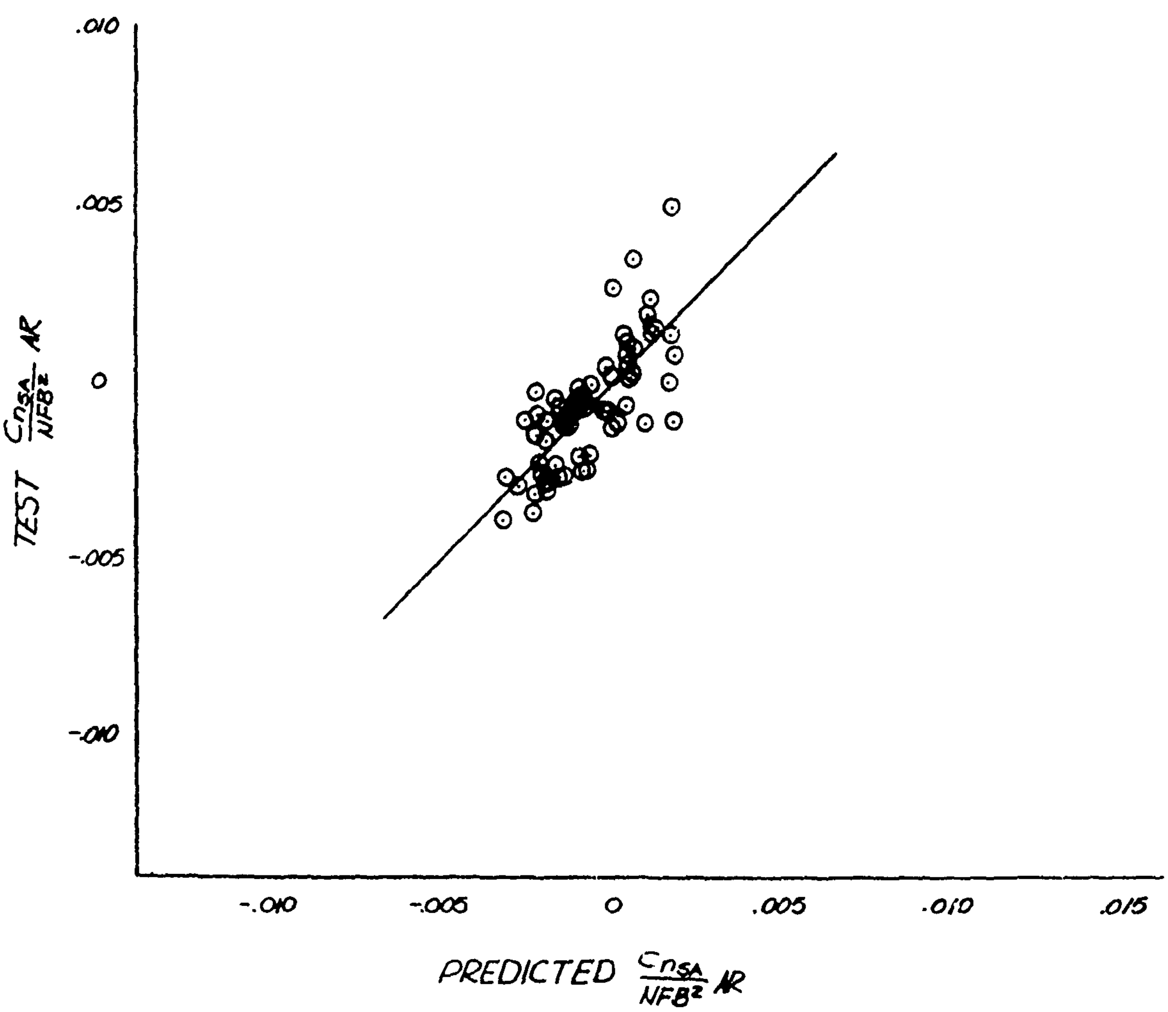
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK
INBOARD
YAWING MOMENT COEFFICIENT

$\alpha = 6^\circ, \quad \beta = +10^\circ$

$MN = .6 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{NS_A}}{NFB^2} AR = -.0422681 - .0000107\ell + .0036010D - .0001237C - .0000949\Delta X - .0000055 \frac{SA}{FA} \times FSPD - .0023545M^2$$



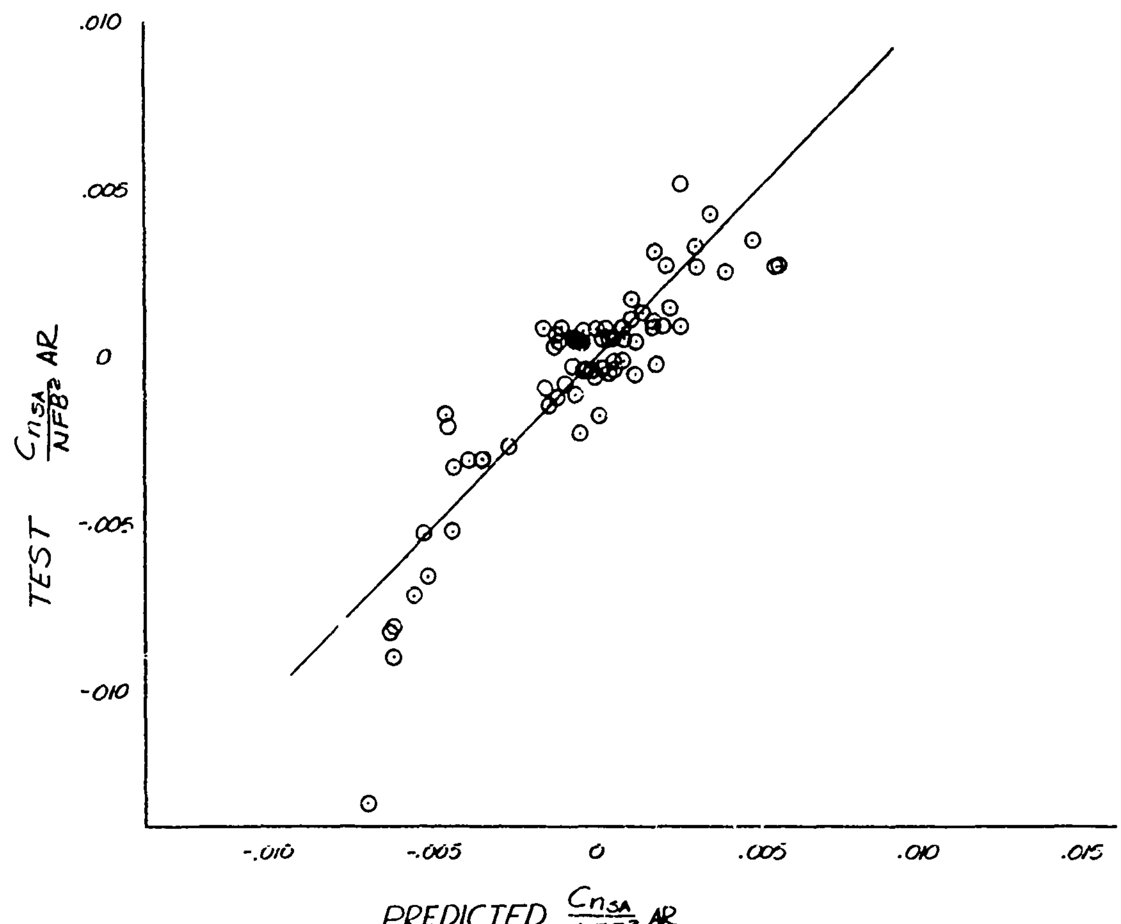
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK
INBOARD
YAWING MOMENT COEFFICIENT

$\alpha = 6^\circ, \quad \beta = -10^\circ$

$MN = .6 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{NSA}}{NFB^2}\,AR = .0880471 - .0000079\ell - .0031223D - .0002538C + .0000631\Delta X - .0000231\,\frac{SA}{FA} \times FSPD - .0032364M2$$



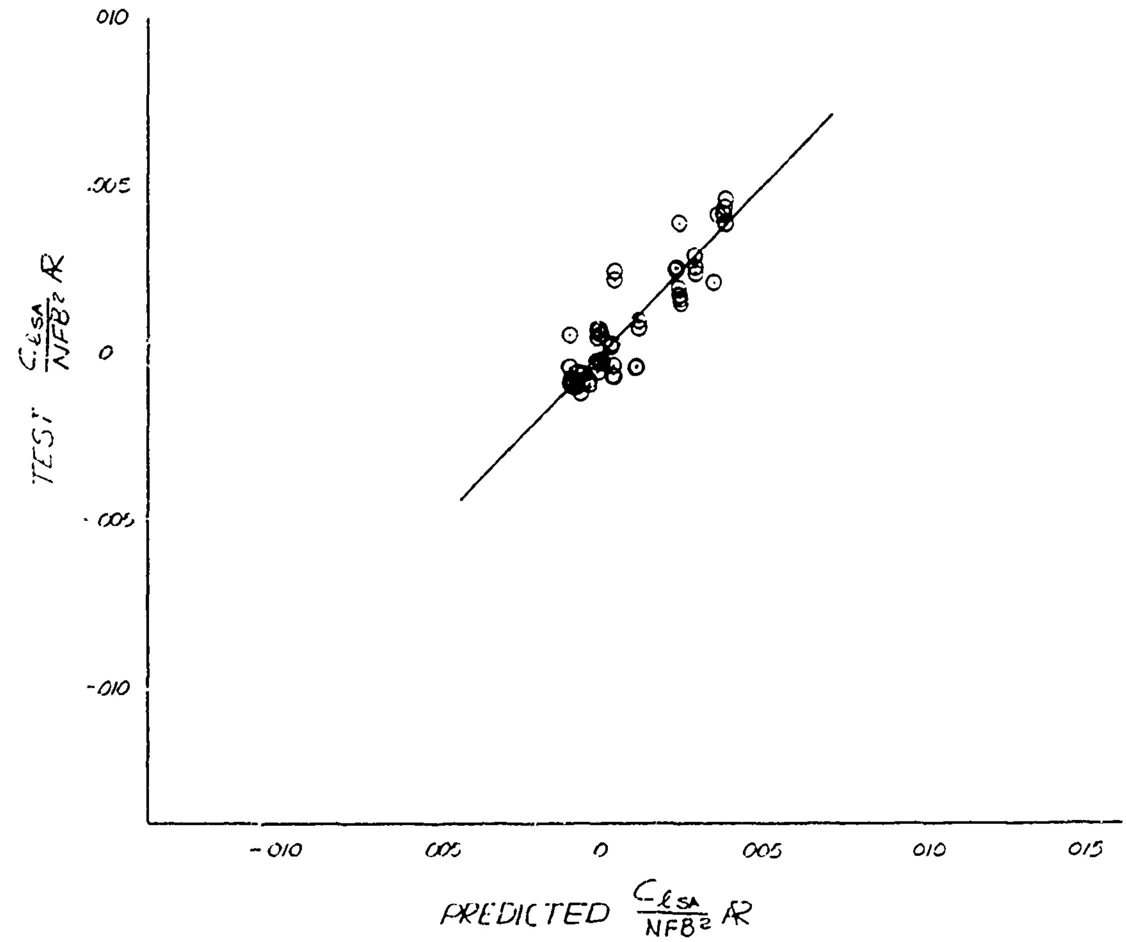
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK
INBOARD
ROLLING MOMENT COEFFICIENT

$\alpha = 16^\circ, \ \beta = 0^\circ$

MN = .6 - .95

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

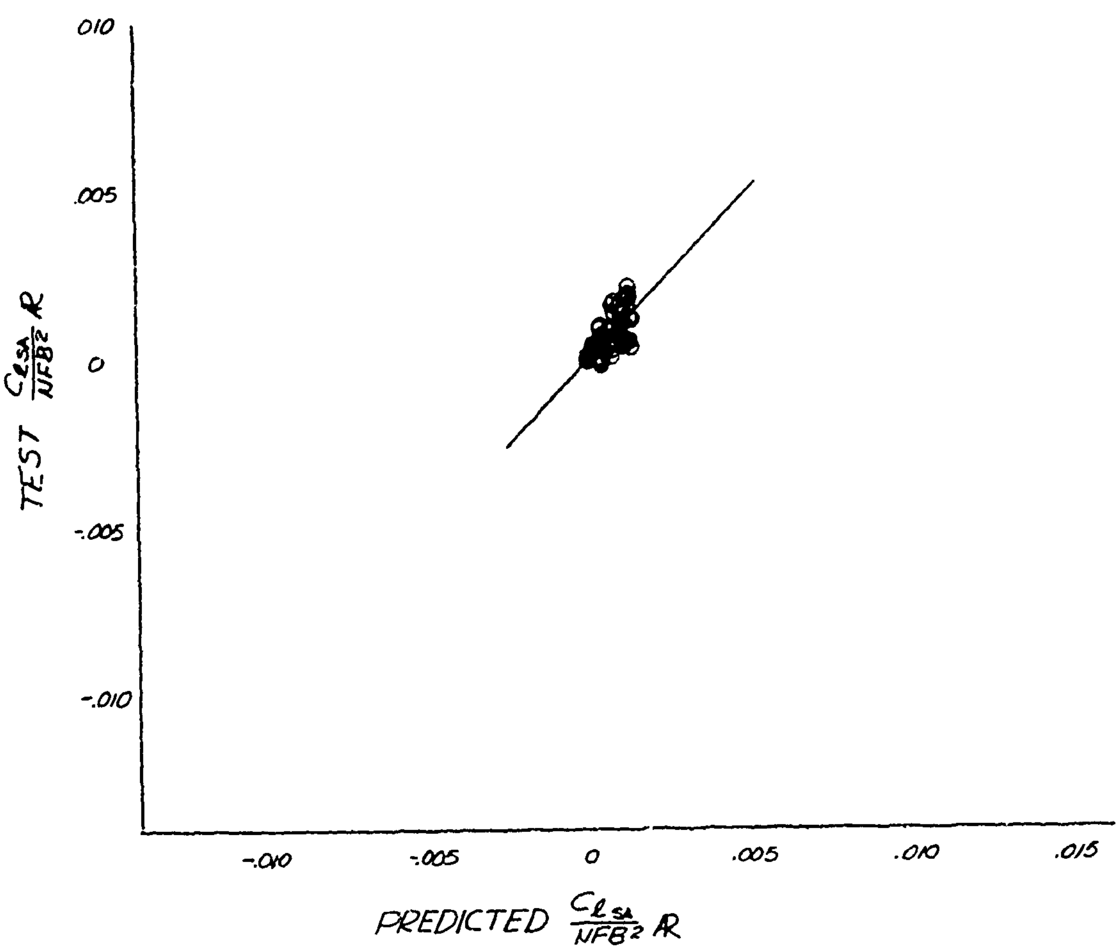
$$\frac{C_{l_{SA}}}{NFB^2} AR = .- .0221949 + .0000296\ell + .0013328D - .0000212C - .0000440\Delta X + .0000022 \frac{SA}{FA} \times FSPD + .0000266M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK
INBOARD
ROLLING MOMENT COEFFICIENT

$\alpha = 6^o, \quad \beta = 0^o$
MN = .6 - .95
= $16^o - 72.5^o$

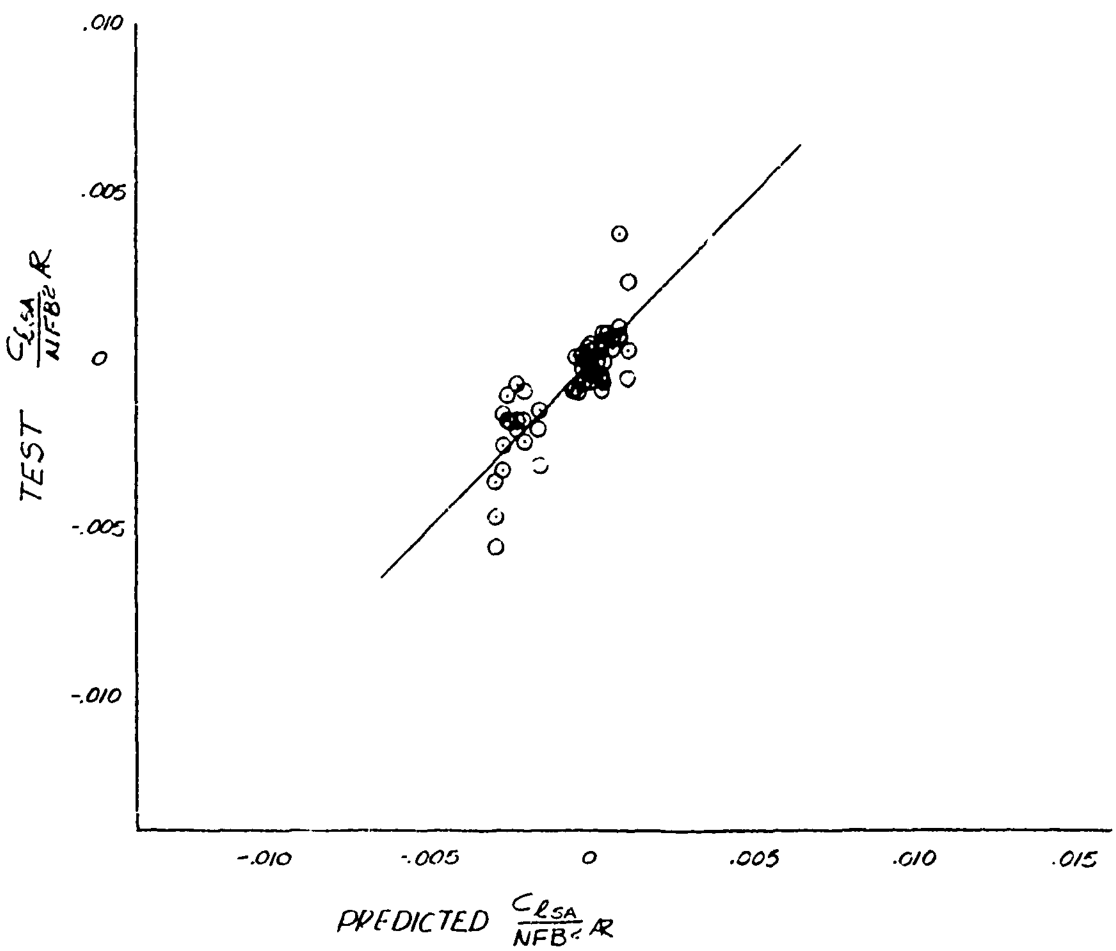
$$\frac{C_{\ell SA}}{NFB^2} AR = -.0176370 - .0000228\ell + .0015012D - .0000390C - .0000068\Delta X - .0000023 \frac{SA}{FA} \times FSPD + .0000432M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK
INBOARD
ROLLING MOMENT COEFFICIENT

$\alpha = -4^\circ$, $\beta = 0^\circ$
MN = .6 - .95
$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{\ell SA}}{NFB^2} \text{ AR} = .0585330 + .0000385\ell - .0025070D - .0001530C + .0000094\Delta X - .0000128 \frac{SA}{FA} \times \text{FSPD} + .0000417M^2$$



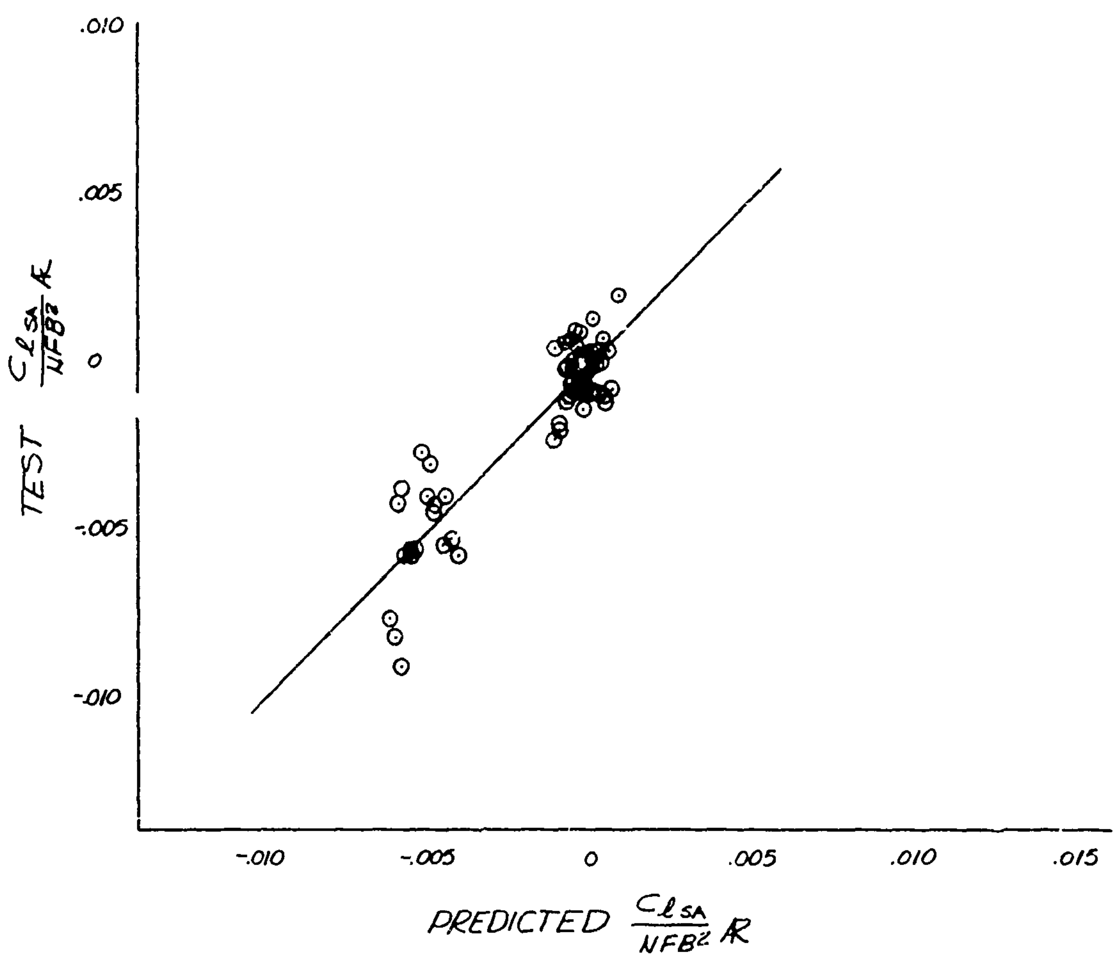
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK
INBOARD
ROLLING MOMENT COEFFICIENT

$\alpha = -9°, \ \beta = 0°$

MN = .6 - .95

$\Lambda_{LE} = 16° - 72.5°$

$$\frac{C_{\ell SA}}{NFB^2} \ AR = . \ .0925557 + .0000612\ell - .0046203D - .0001648C + .0000004\Delta X - .0000140 \frac{SA}{FA} \times FSPD + .0006644M^2$$



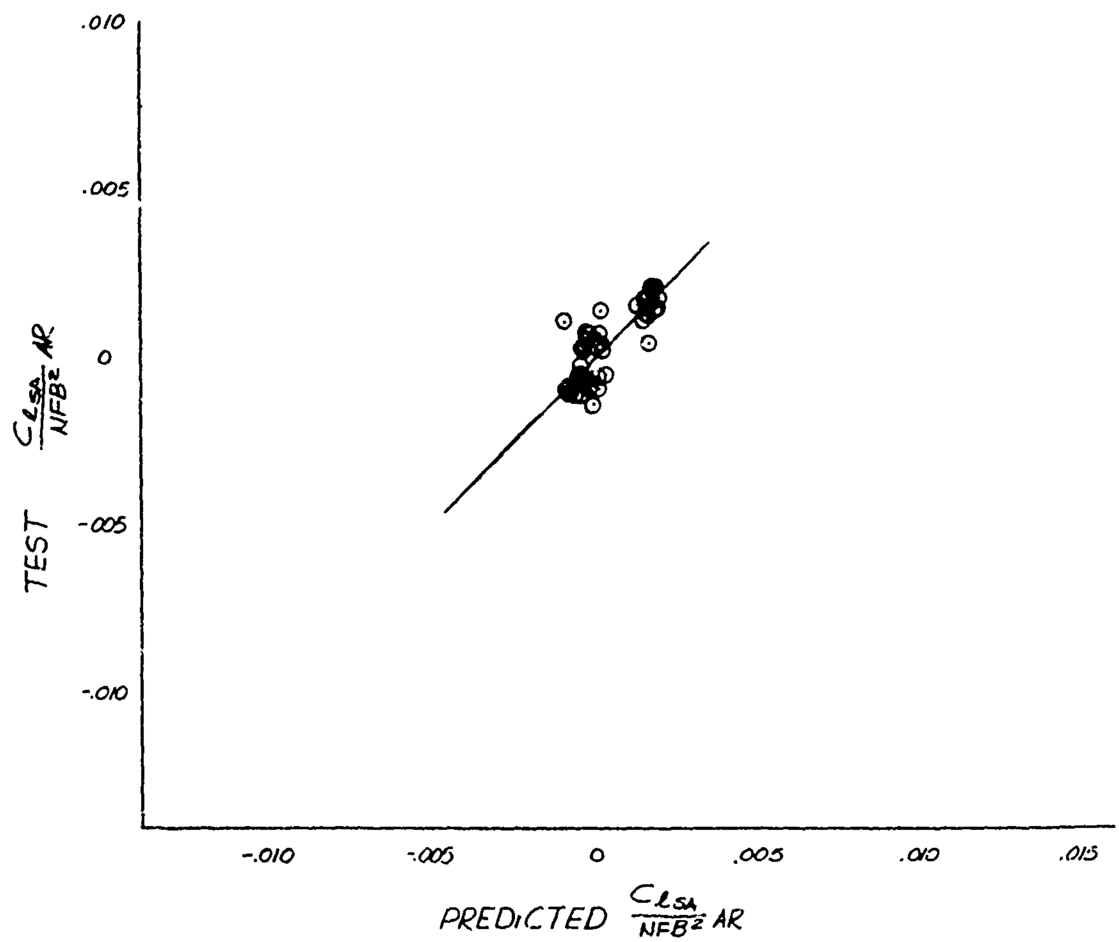
COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK
INBOARD
ROLLING MOMENT COEFFICIENT

$\alpha = 6^\circ, \quad \beta = \pm 10^\circ$

MN = .6 - .95

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

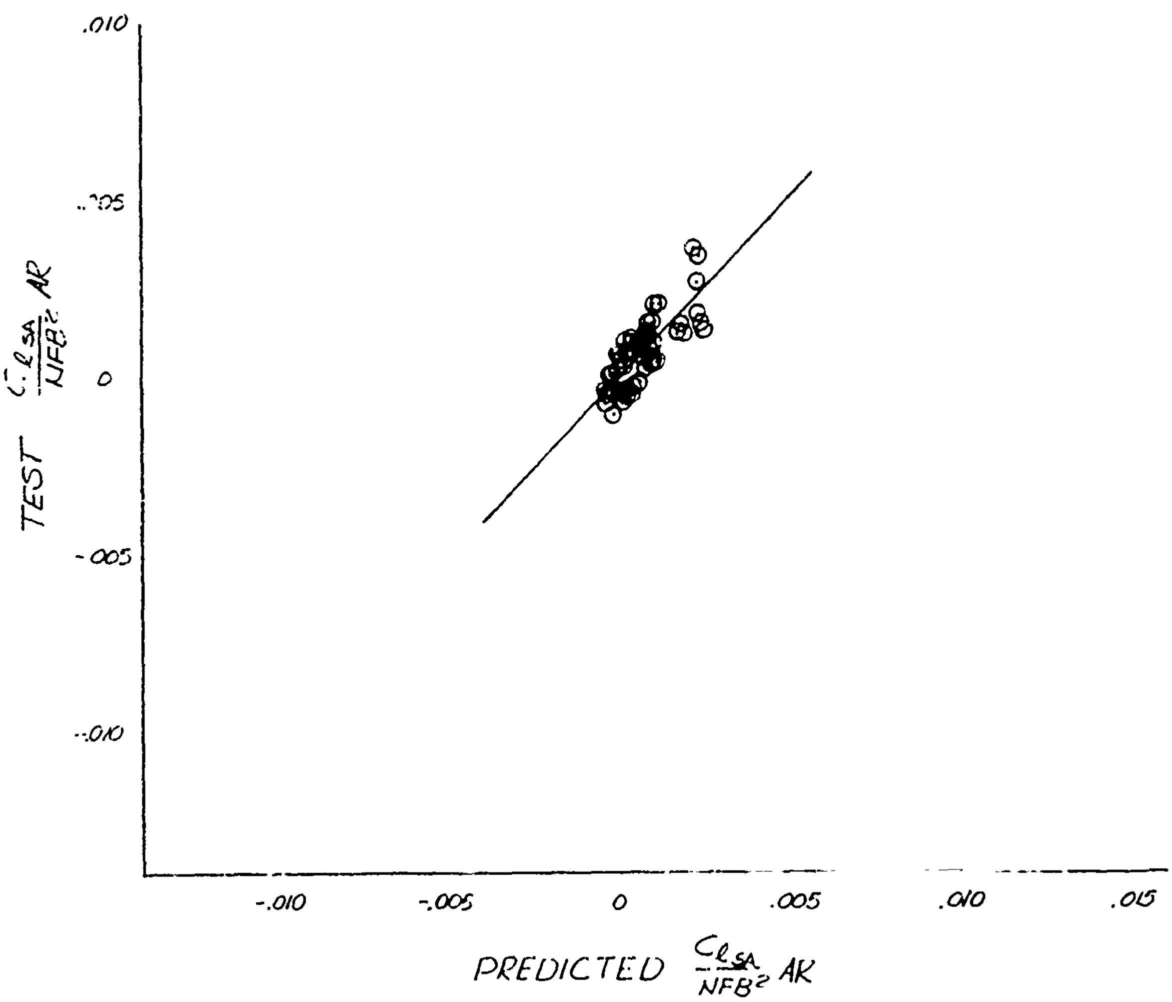
$$\frac{C_{l_{SA}}}{NFB^2} AR = -.0142329 + .0000256\ell + .0010326D - .0000409C - .0000413\Delta X - .0000014 \frac{SA}{FA} \times FSPD + .0003604M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR WEAPON CLUSTER + RACK
INBOARD
ROLLING MOMENT COEFFICIENT

$\alpha = 6^\circ,\ \beta = -10^\circ$
$MN = .6 - .95$
$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{\ell SA}}{NFB^2}\ AR = .0055813 - .0000346\ell + .0004890D - .0000790C + .0000254\Delta X - .0000055\ \frac{SA}{FA} \times FSPD - .0003570M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON

Outboard

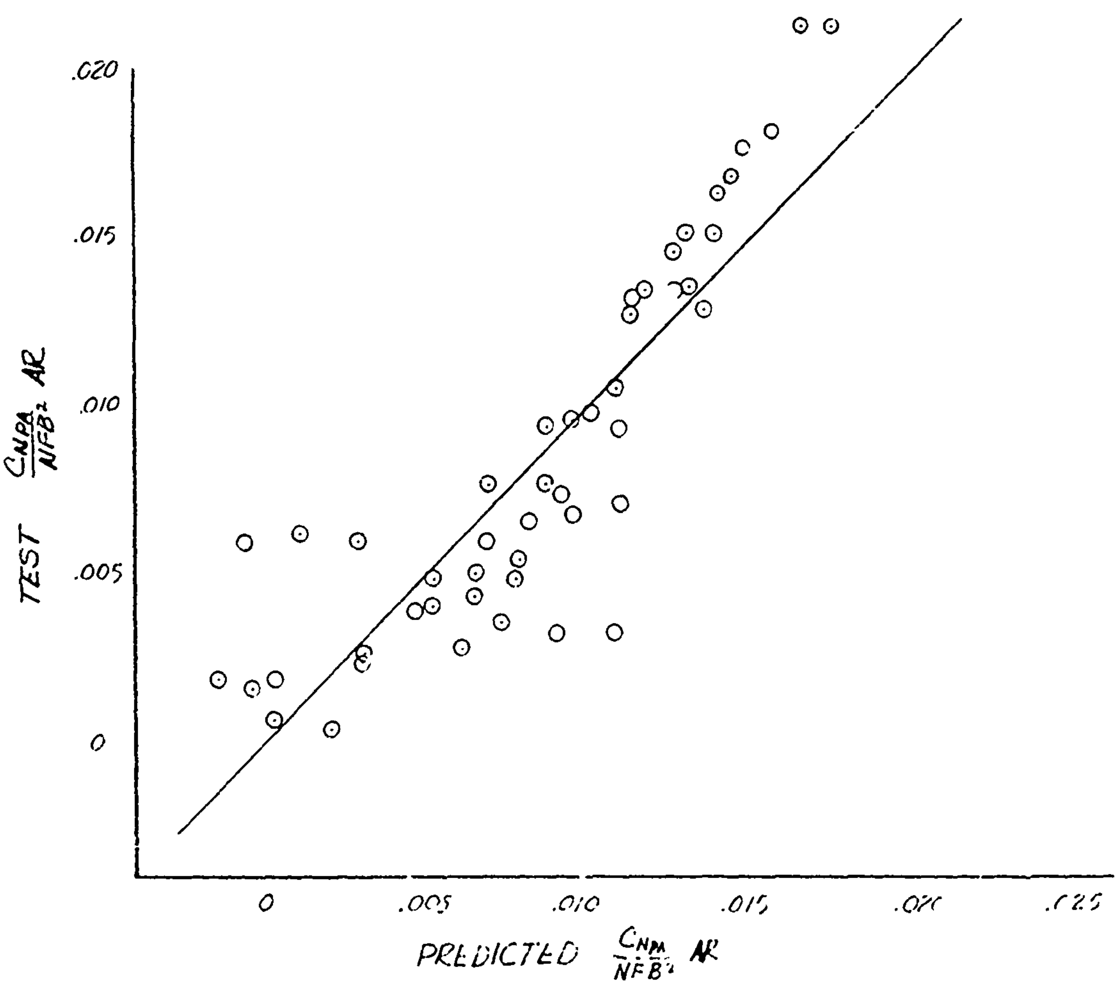
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = 16^\circ, \ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{N_{PA}}}{NFB^2} AR = .1722391 - .0020058\,\ell + .0080600D + .0000543C + .0002888\Delta X - .0000004\,\frac{PA}{FA} \times FSPD - .0064320M^2$$



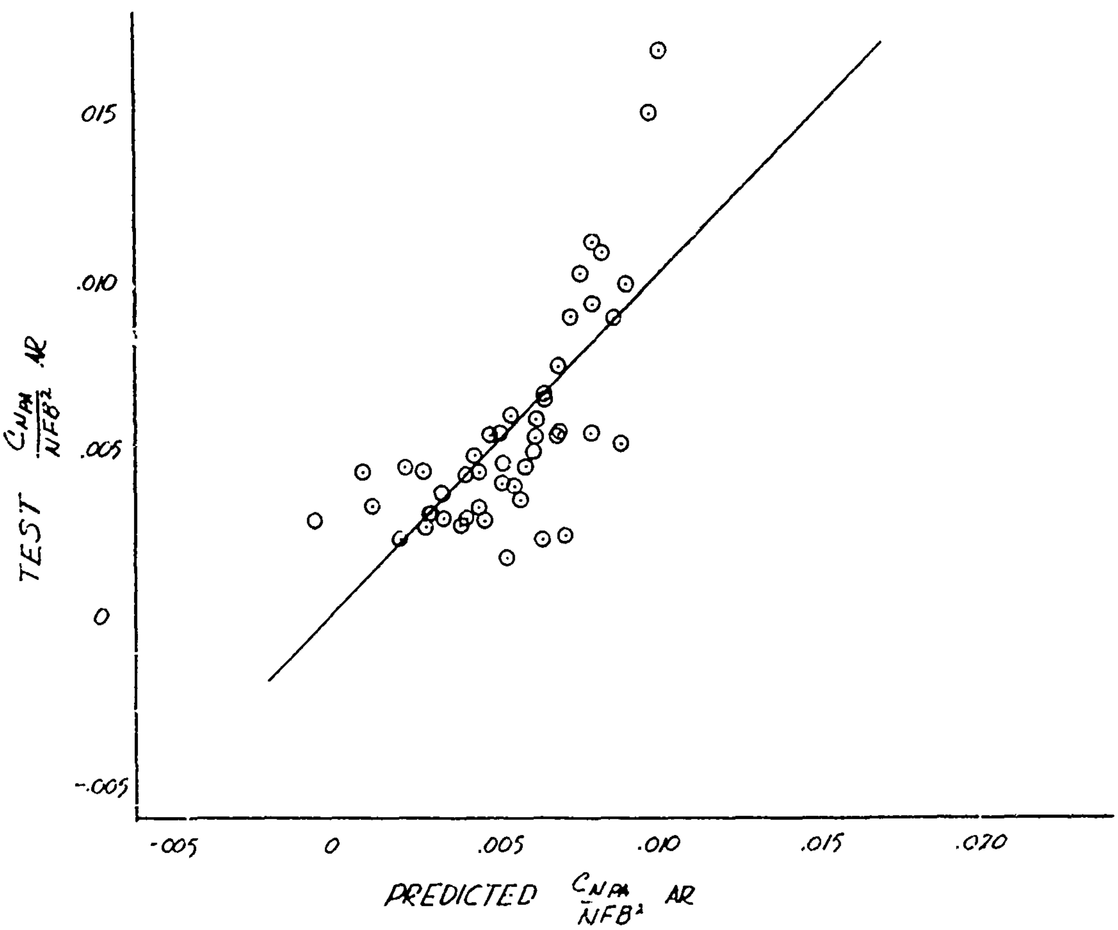
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
NORMAL FORCE COEFFICIENTS

$\alpha_{LOAD} = +6^\circ,\ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{N_{PA}}}{NFB^2}\,AR = -.0686479 + .0004705\,\ell - .0003968D - .0000040C + .0000326\Delta X + .0000025\,\frac{PA}{FA} \times FSPD + .0065590M^2$$



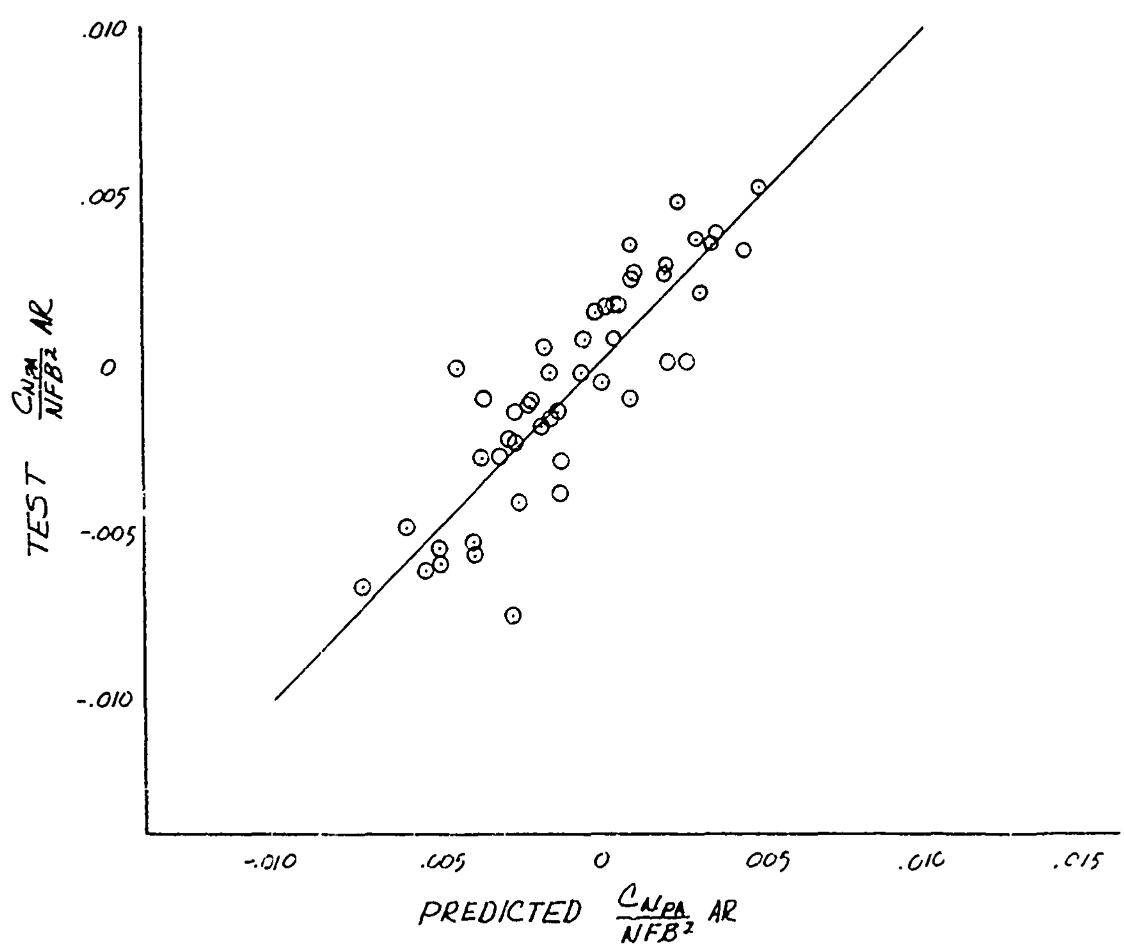
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = -4^\circ,\ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{N_{PA}}}{NFB^2} AR = -.1597513 + .0019066\ell - .0066208D - .00001098C - .0002477\Delta X - .0000024 \frac{PA}{FA} \times FSPD - .0088818M^2$$



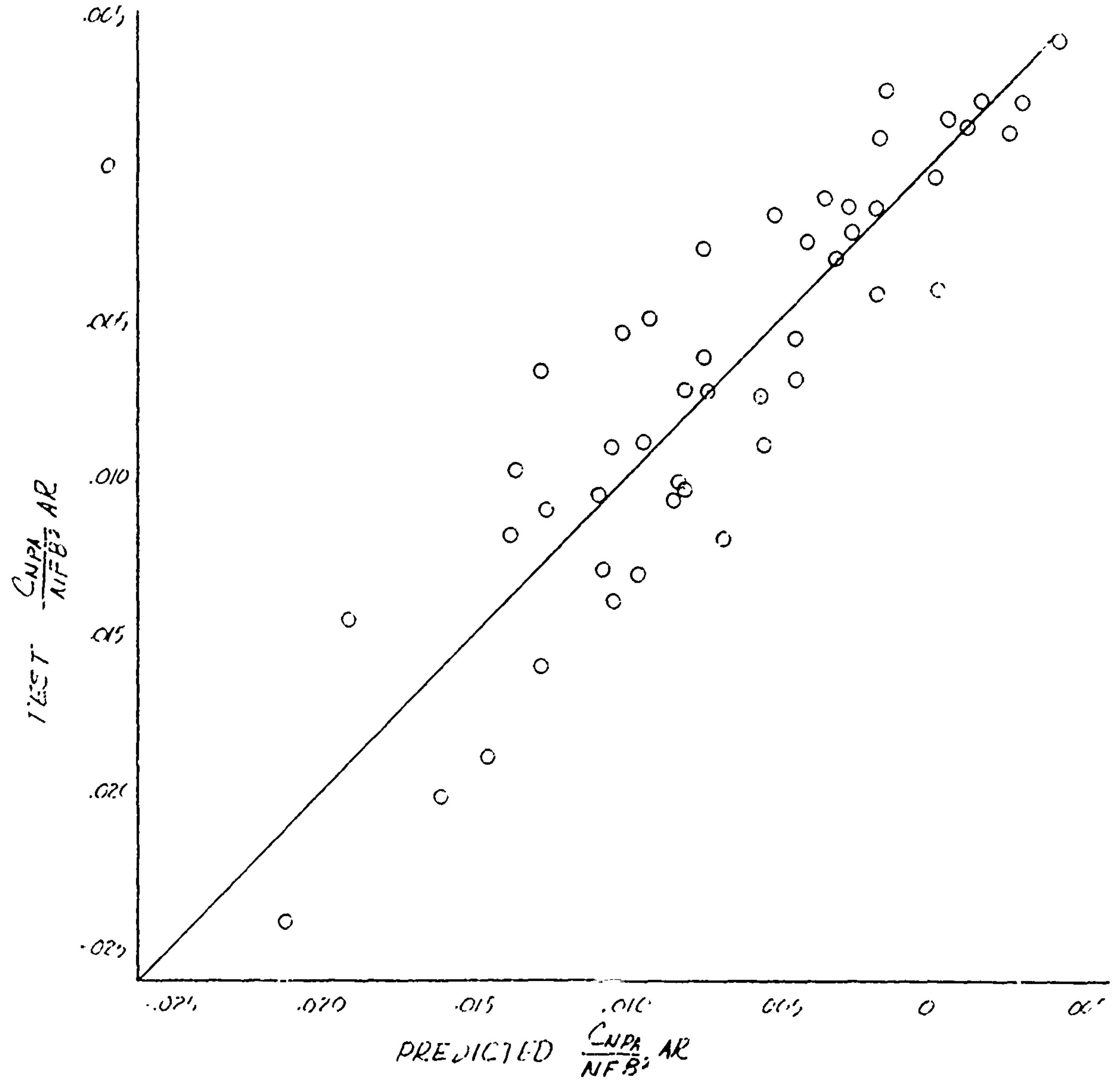
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = -9^\circ, \ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

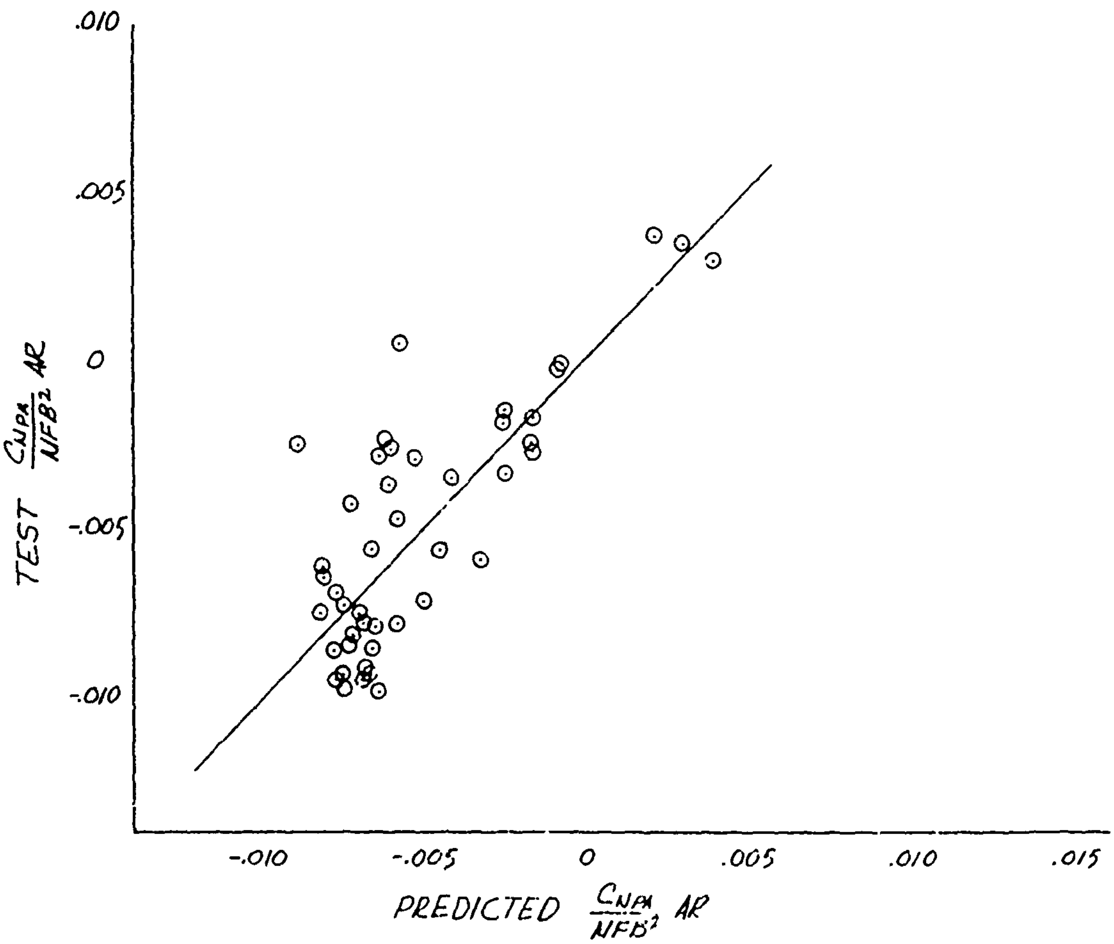
$$\frac{C_{N_{PA}}}{NFB^2} AR = -.2336266 + .0030141\ell - .0107959D - .0002350C - .0004967\Delta X - .0000066\frac{PA}{FA} \times FSPD - .0203926M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
NORMAL FORCE COEFFICIENT

$$\alpha_{LOAD} = 6^\circ,\ \beta = +10^\circ$$
$$M = .60 - .95$$
$$\Lambda_{LE} = 16^\circ - 72.5^\circ$$

$$\frac{C_{N_{PA}}}{NFB^2} AR = .1587650 - .0015536\ell + .0041798D + .0000807C + .0001380\Delta X + .000000002 \frac{PA}{FA} \times FSPD + .0031612M^2$$



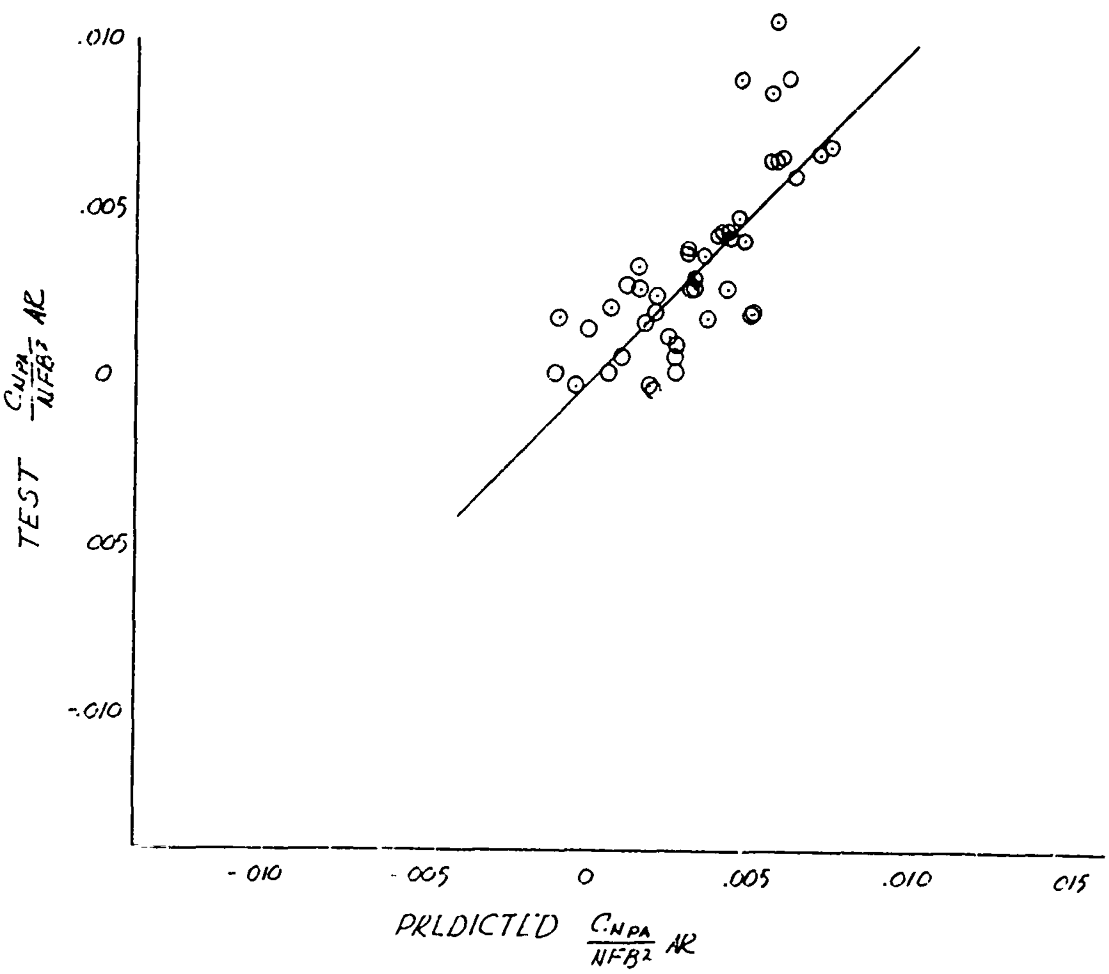
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
NORMAL FORCE COEFFICIENT

$$\alpha_{LOAD} = 6^{\circ},\ \beta = -10^{\circ}$$

$$M = .60 - .95^{\circ}$$

$$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$$

$$\frac{C_{N_{PA}}}{NFB^2} AR = -.0273567 + .0000786\,\ell + .0004042D + .0000164C + .0000961\Delta X - .0000030\,\frac{PA}{FA} \times FSPD + .0057234M^2$$



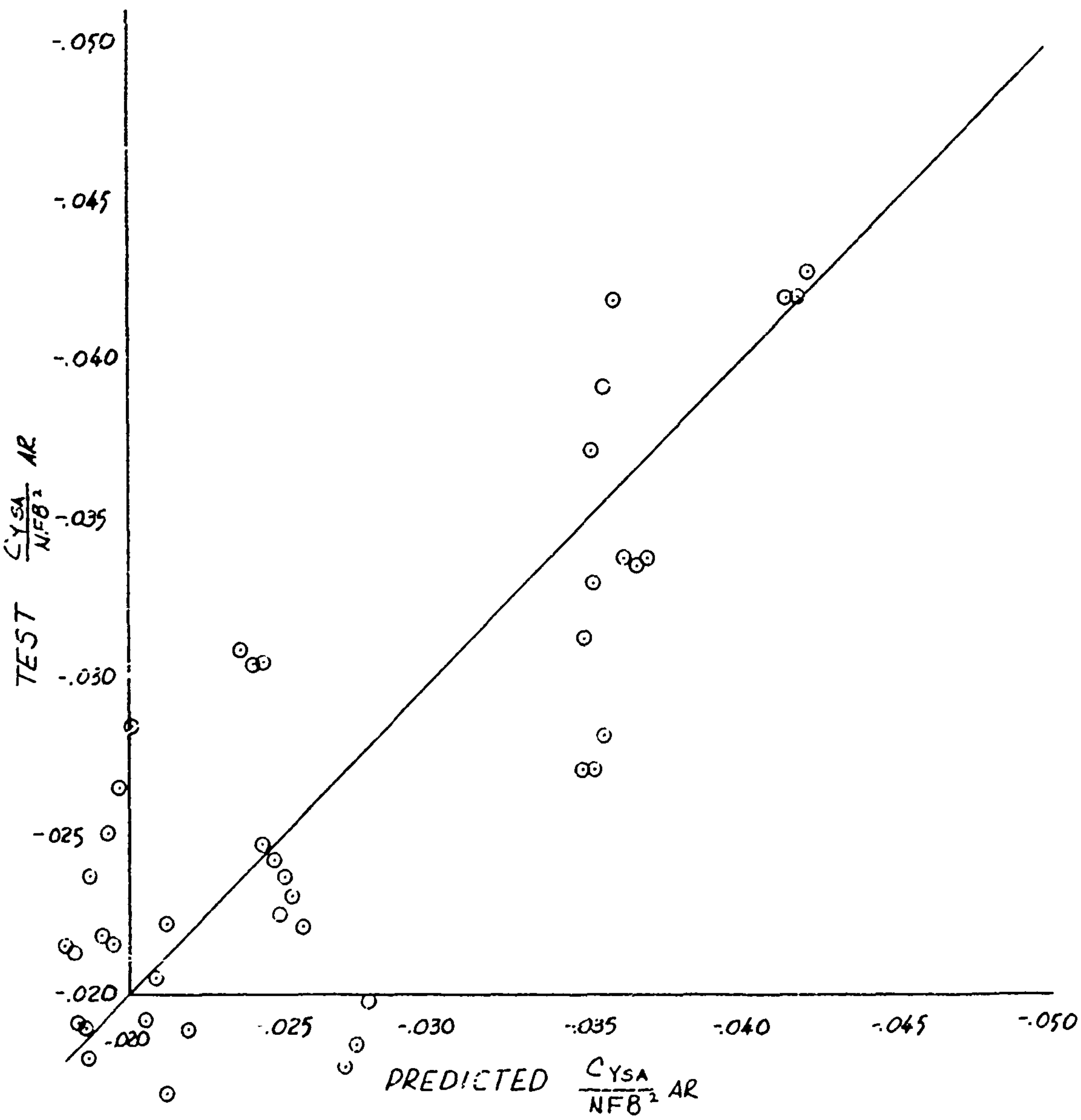
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = 16^\circ,\ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = .4706168 - .0033429\ell + .0074145D - .0003203C - .0004273\Delta X - .0000111 \frac{SA}{FA} \times FSPD - .0013383M^2$$



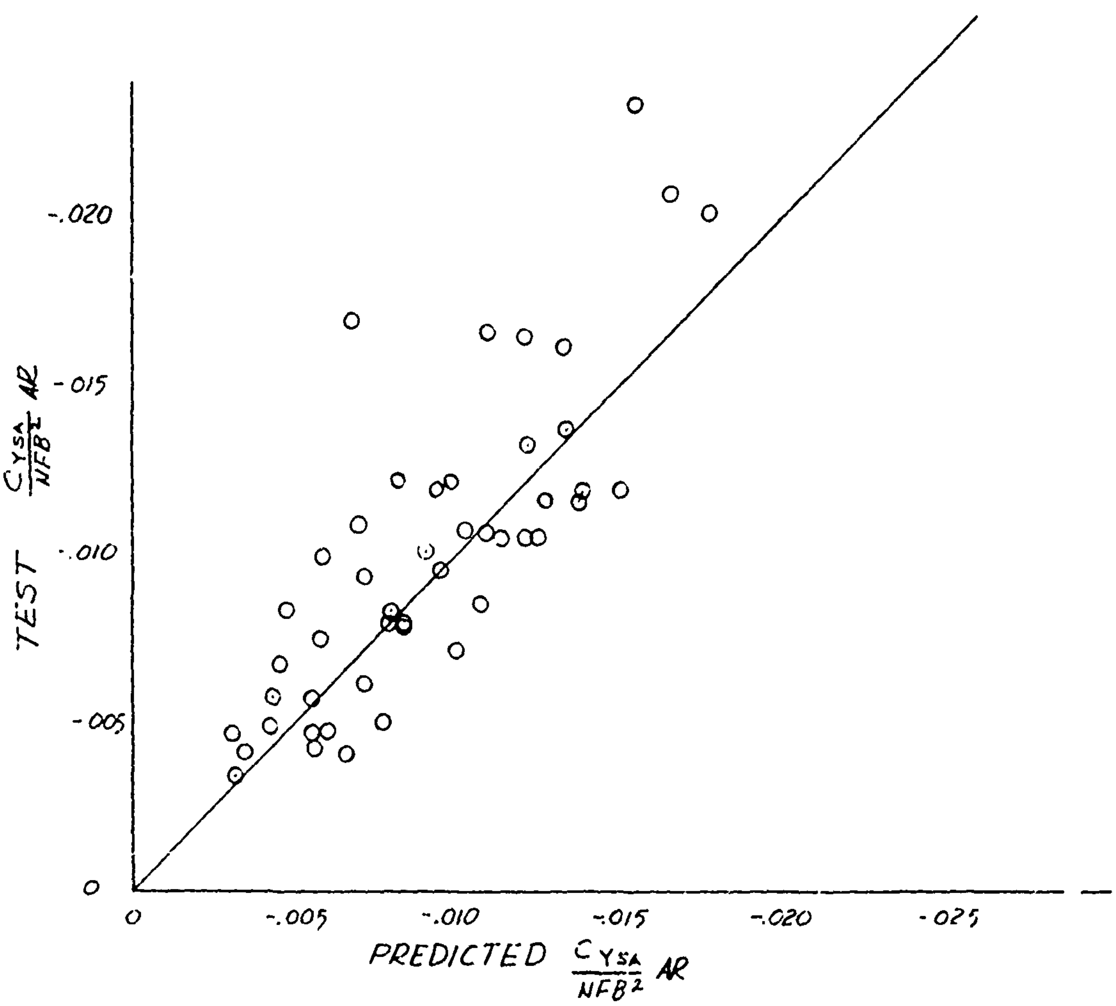
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = 6^\circ,\ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = .2500346 - .0018354\ell + .0042186D - .0001279C - .0001920\Delta X - .0000080\frac{SA}{FA} \times FSPD + .0043464M^2$$



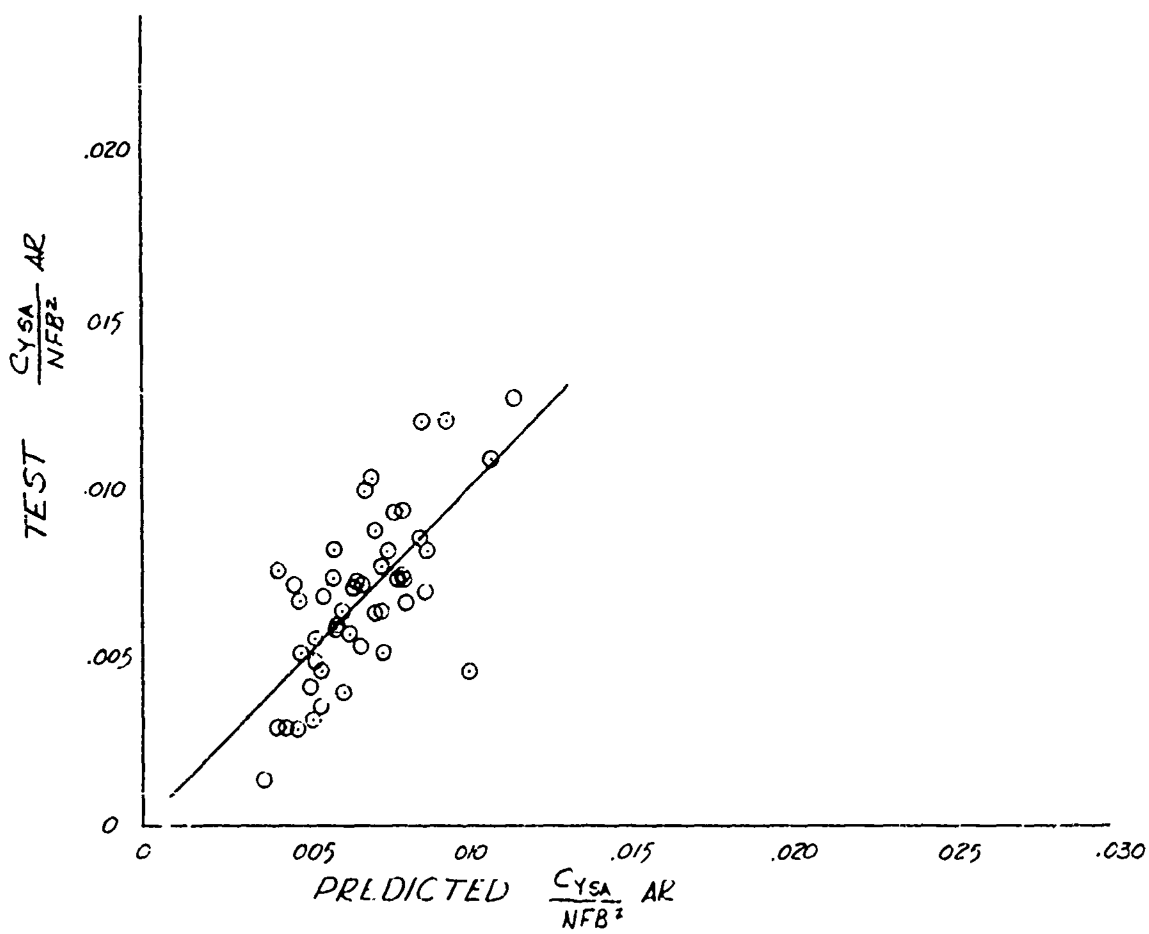
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = -4^{\circ},\ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

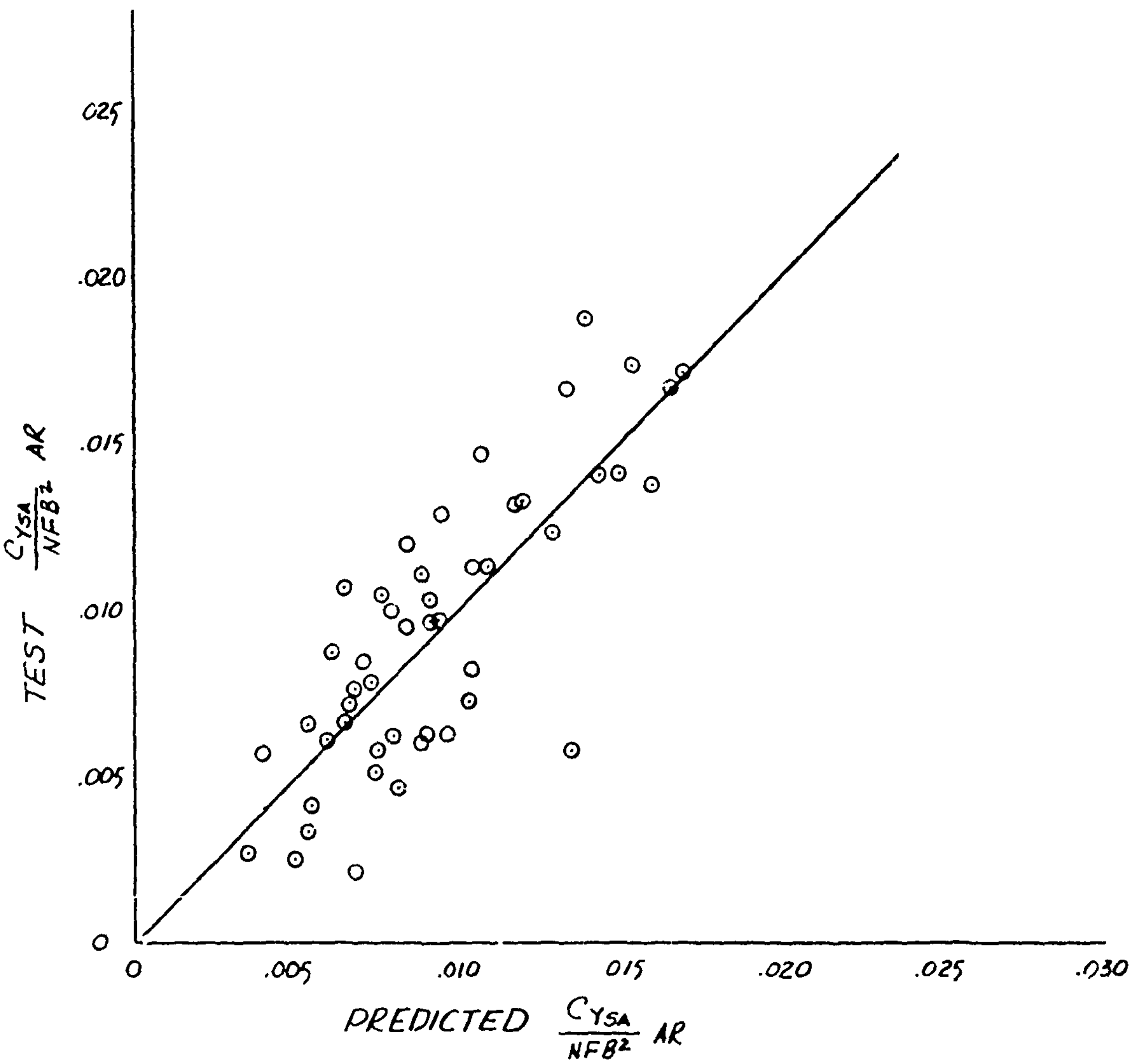
$$\frac{C_{Y_{SA}}}{NFB^2} AR = .0476157 - .0001773\ell + .0000471D - .0000265C - .0000844\Delta X - .000003'' \frac{SA}{FA} \times FSPD - .0052017M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
SIDE FORCE COEFFICIENT

$$\alpha_{LOAD} = -9^{\circ},\ \beta = 0^{\circ}$$
$$M = .60 - .95$$
$$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = -.057248 + .0007701\ell - .0029604D + .0000151C - .0000812\Delta X - .0000008 \frac{SA}{FA} \times FSPD - .0056539M^2$$



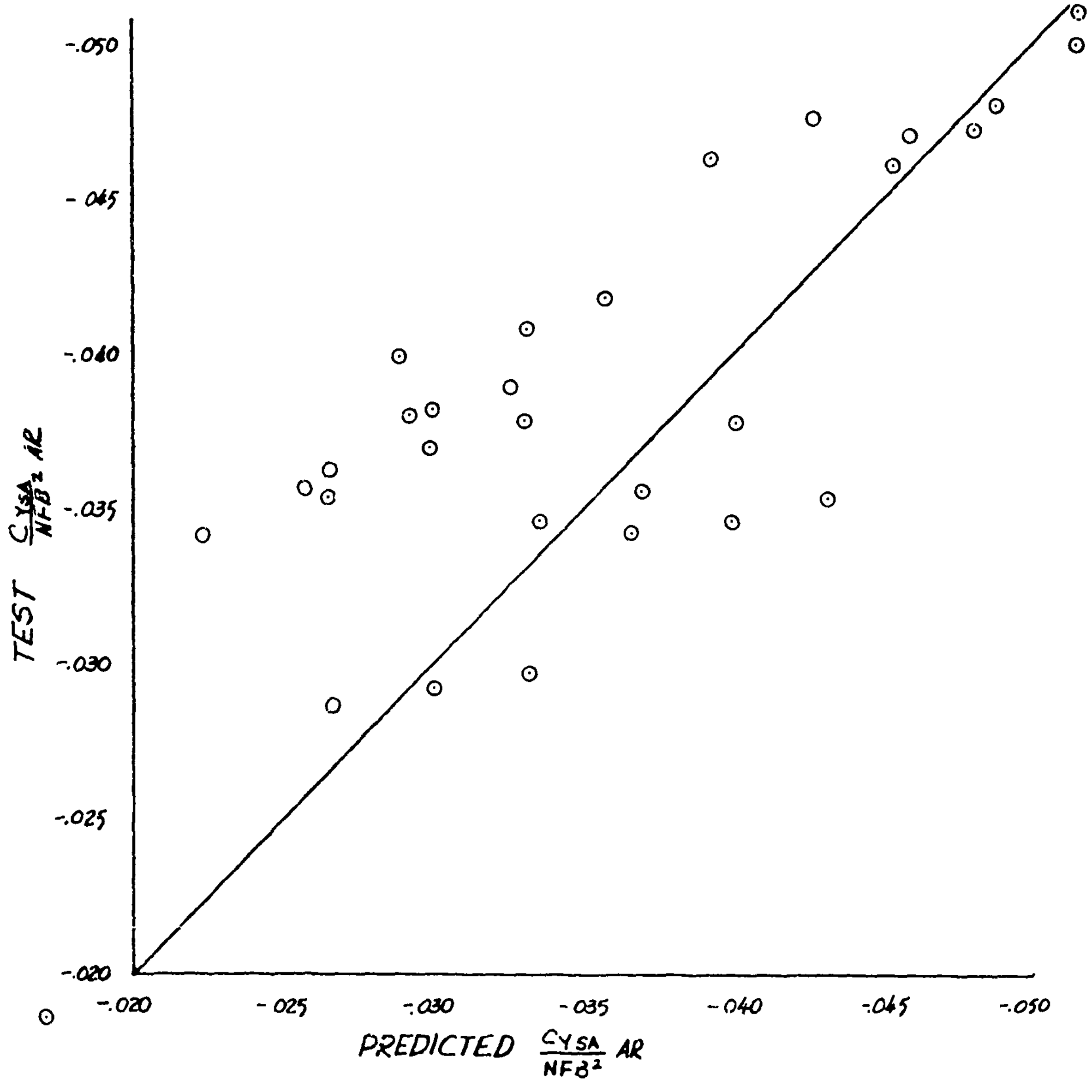
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \beta = +10^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = .7757195 - .0054813\ell + .0111078D - .0003071C - .0007301\Delta X - .0000247 \frac{SA}{FA} \times FSPD - .0120978M^2$$



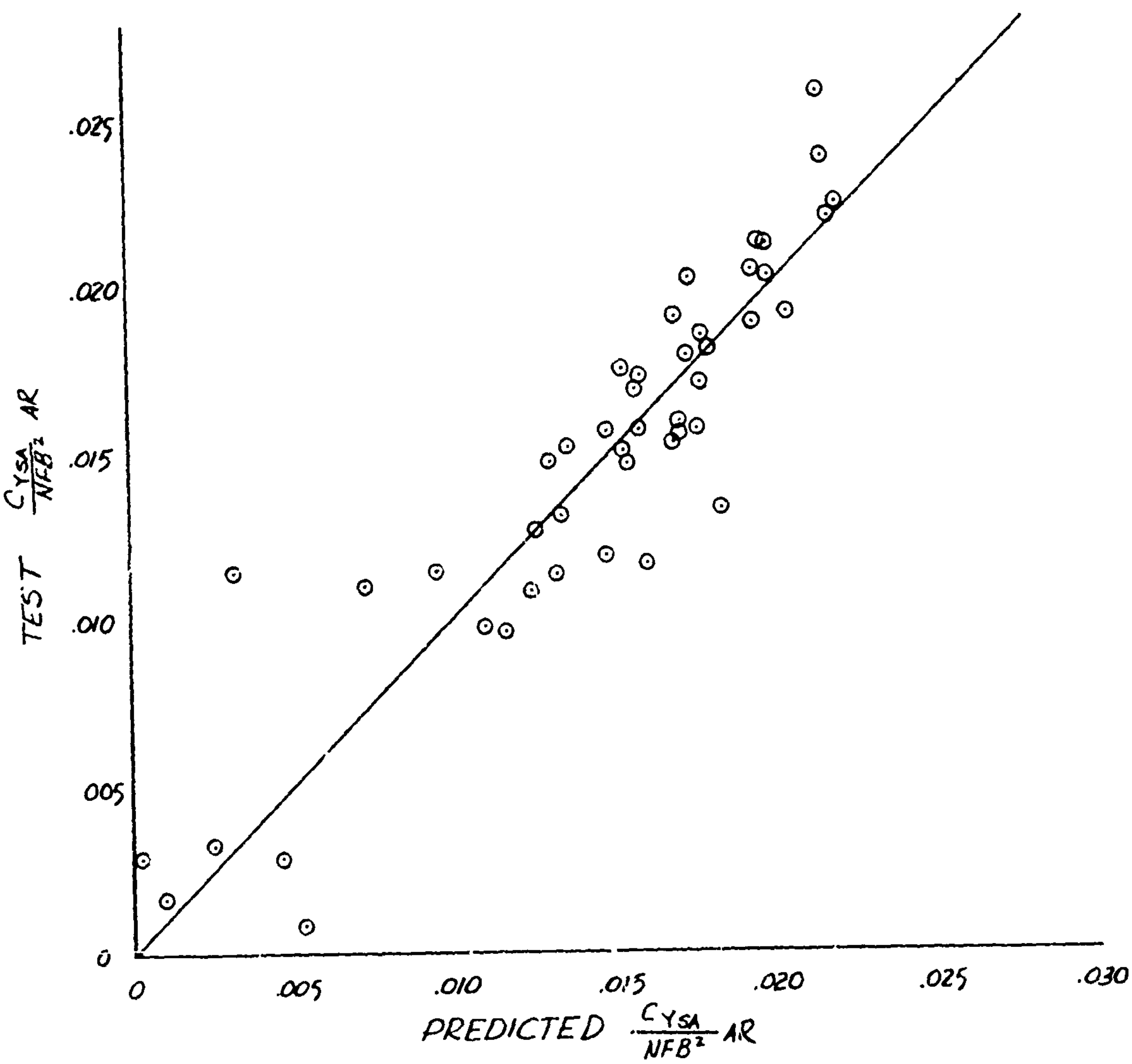
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \beta = -10^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = .0683961 - .0002651\ell + .0008327D - .0001587C - .0001595\Delta X - .0000021\frac{SA}{FA} \times FSPD + .0081253M^2$$



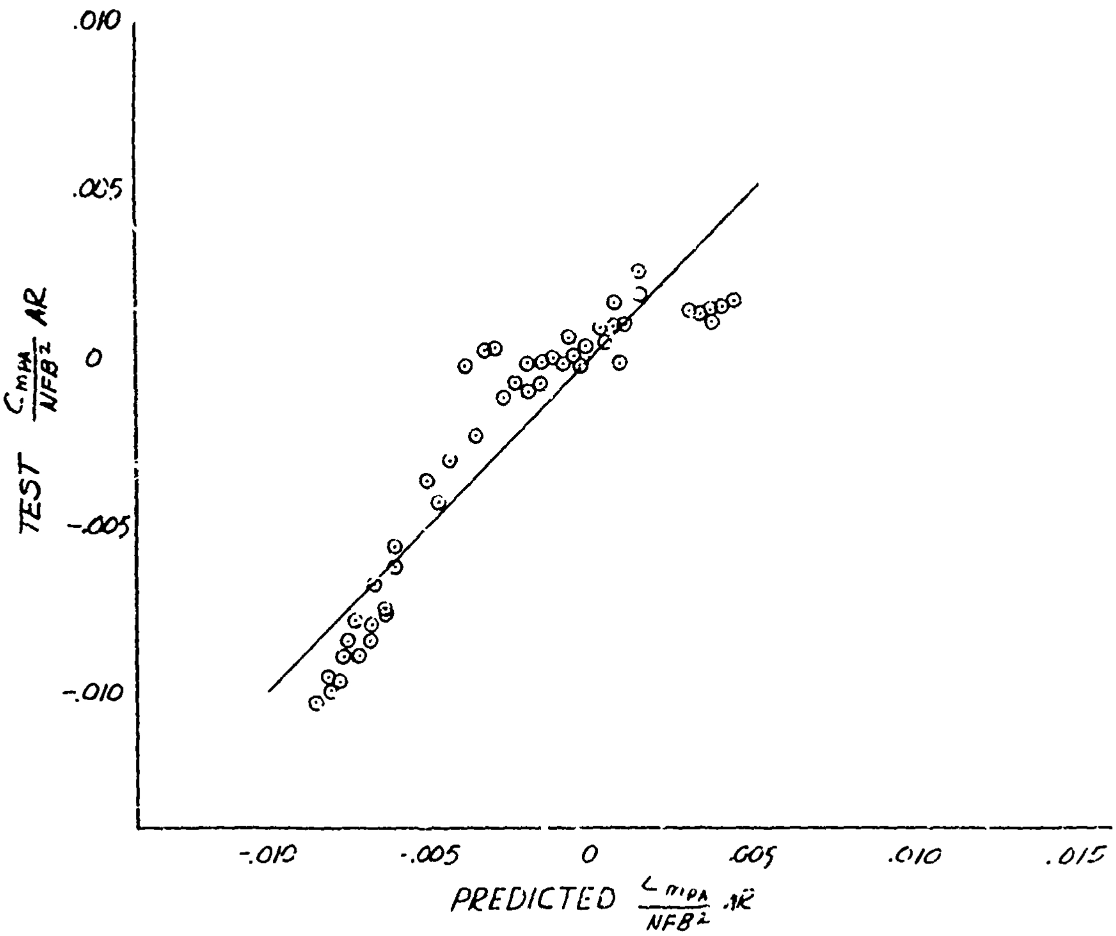
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
PITCHING MOMENT COEFFICIENT

$$\alpha_{LOAD} = 16^{\circ},\ \beta = 0^{\circ}$$

$$M = .60 - .95$$

$$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$$

$$\frac{C_{m_{PA}}}{NFB^2} AR = -.2043476 + .0021835\ell - .0080394D - .0000211C$$
$$-.0001625\Delta X + .0000013\frac{PA}{FA} \times FSPD + .0013059M^2$$



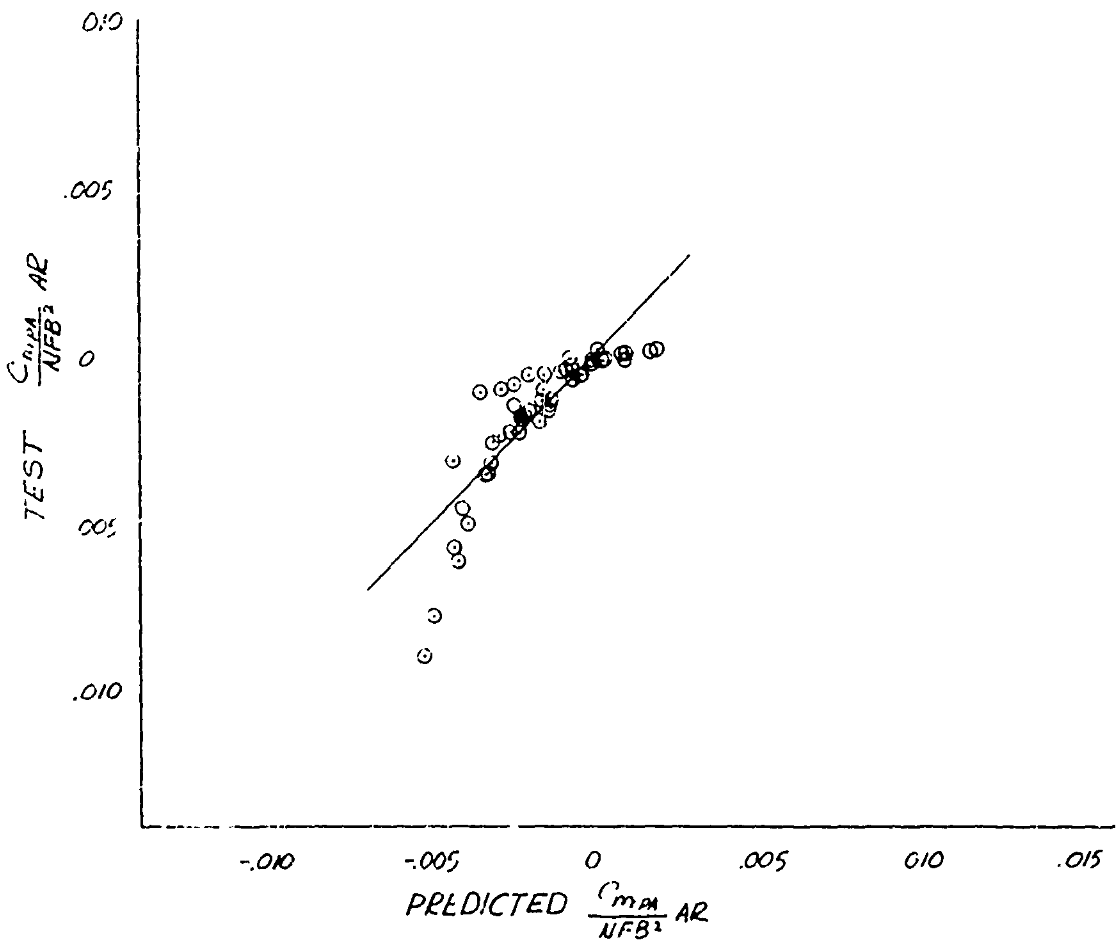
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
PITCHING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{m_{PA}}}{NFB^2} AR = -.0609364 + .0007047\ell - .0027231D - .0000063C$$
$$-.0000559\Delta X - .0000007 \frac{PA}{FA} \times FSPD - .0034125M^2$$



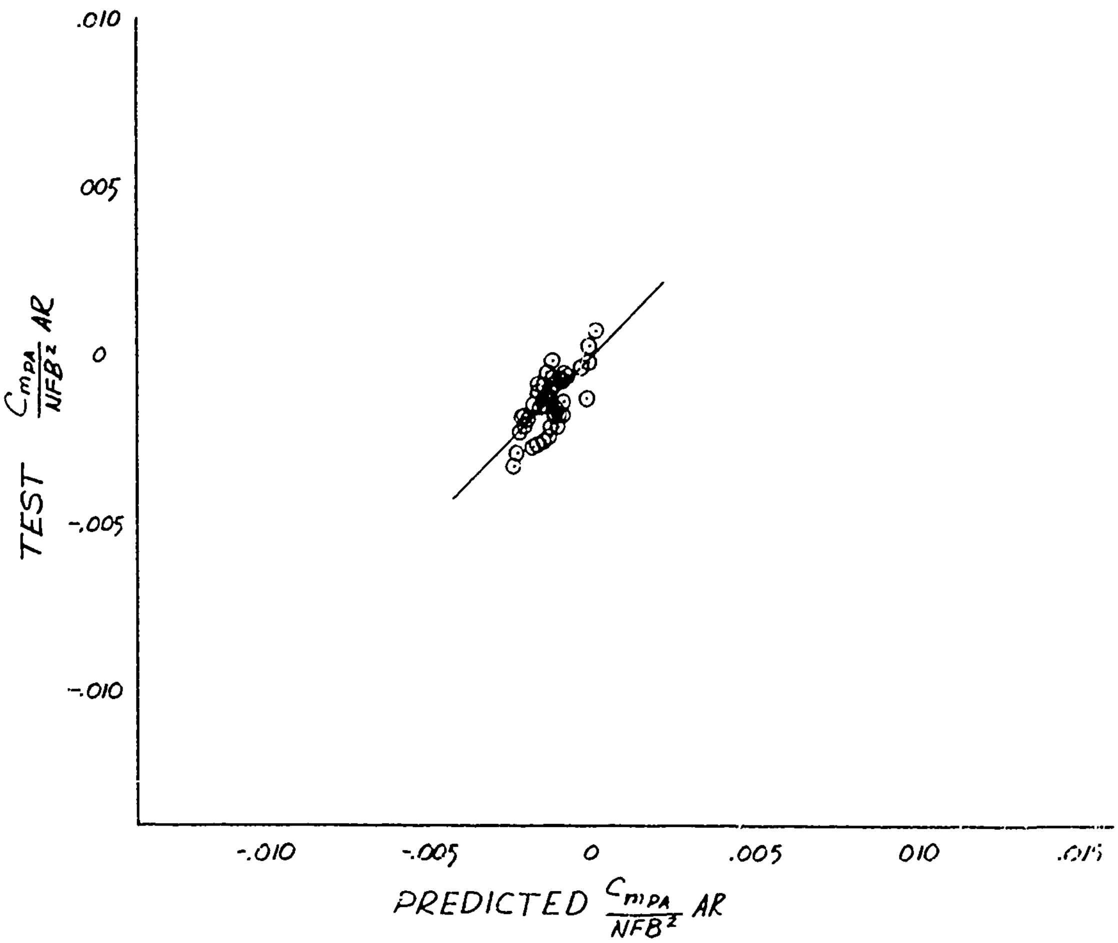
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
PITCHING MOMENT COEFFICIENT

$\alpha_{LOAD} = -4^{\circ}$, $\beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

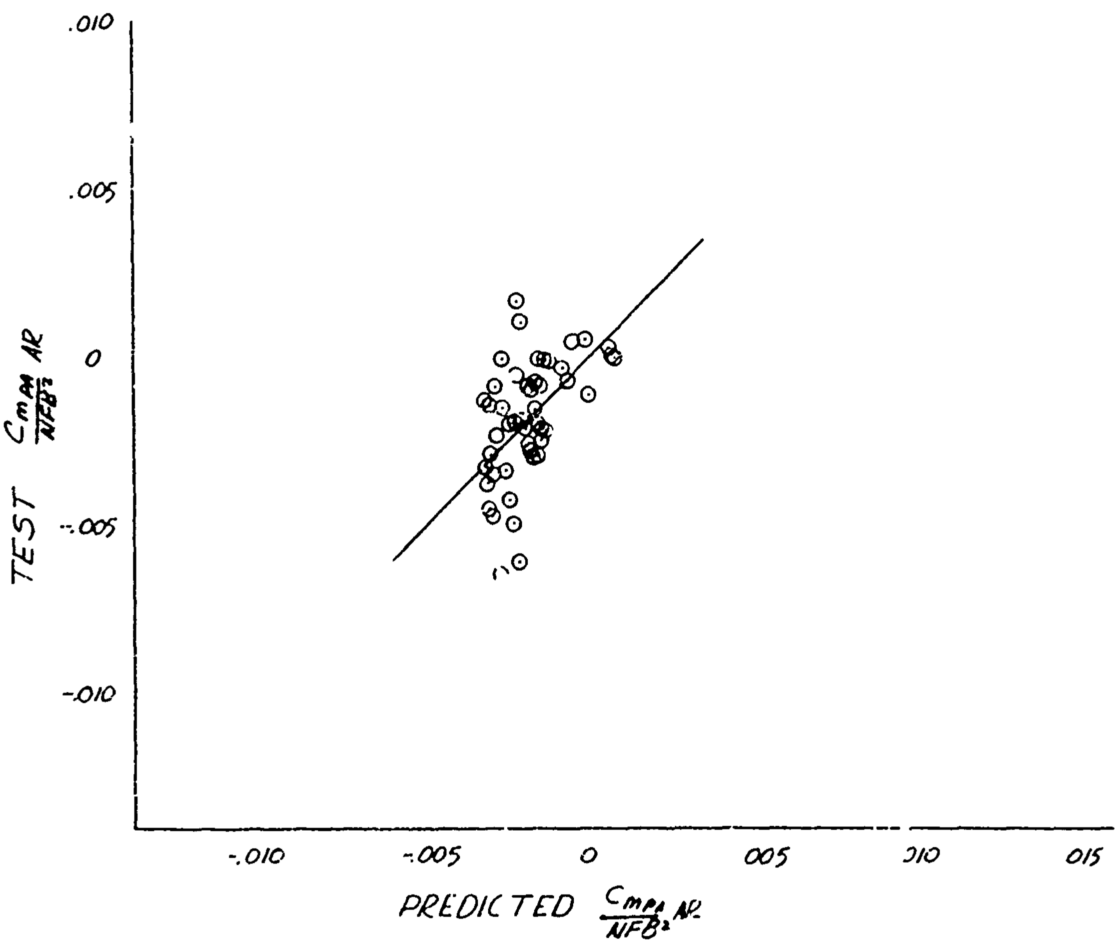
$$\frac{C_{m_{PA}}}{NFB^2} AR = .0187077 - .0003014\ell + .0011525D + .0000354C + .0000763\Delta X + .0000006 \frac{PA}{FA} \times FSPD - .0004960M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
PITCHING MOMENT COEFFICIENT

$$\alpha_{LOAD} = -9^{\circ},\ \beta = 0^{\circ}$$
$$M = .60 - .95$$
$$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$$

$$\frac{C_{m_{PA}}}{NFB^2} AR = .0247420 - .0003833\,\ell + .0013170D + .0000539C + .0001090\Delta X + .0000004\,\frac{PA}{FA} \times FSPD + .0004358M^2$$



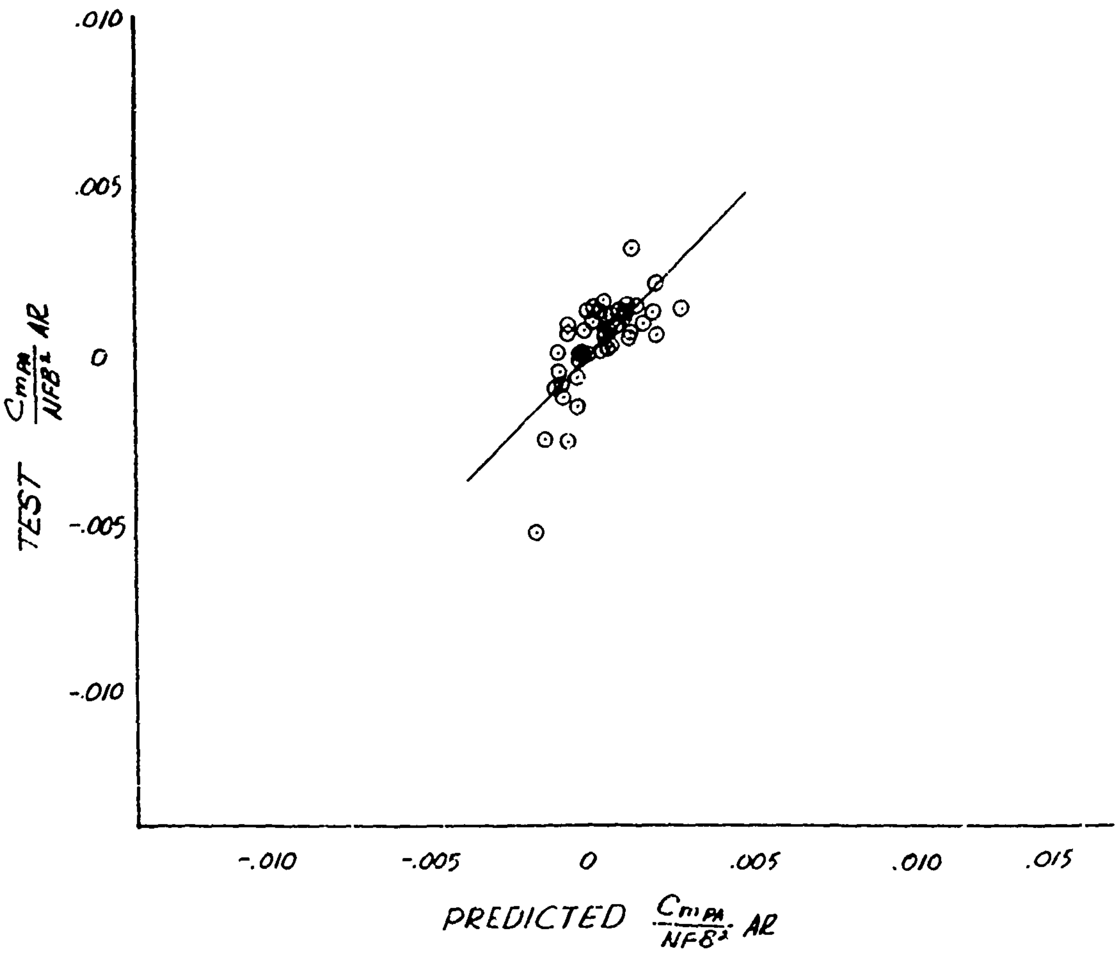
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
PITCHING MOMENT COEFFICIENT

$\alpha_{LOAD} = +6^\circ,\ \beta = +10^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{m_{PA}}}{NFB^2}\,AR = -.0591299 + .0007105\ell - .0025053D - .0000368C - .0000982\Delta X - .0000006\,\frac{PA}{FA} \times FSPD - .0028513M^2$$



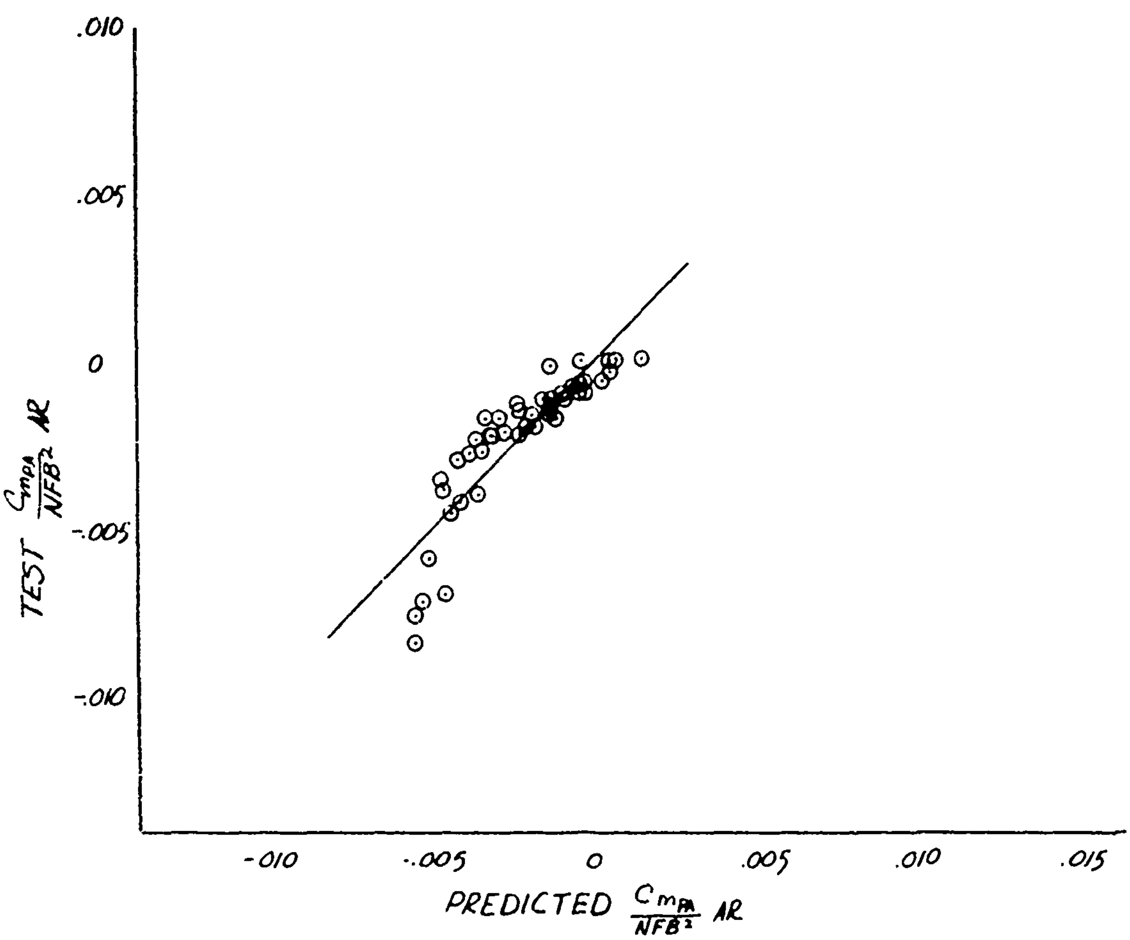
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
PITCHING MOMENT COEFFICIENT

$$\alpha_{LOAD} = 6^\circ,\ \beta = -10^\circ$$

$$M = .60 - .95$$

$$\Lambda_{LE} = 16^\circ - 72.5^\circ$$

$$\frac{Cm_{PA}}{NFB^2} AR = -.1241960 + .0013389\ell - .0047829D - .0000277C - .0001186\Delta X + .0000022 \frac{PA}{FA} \times FSPD - .0034251M^2$$



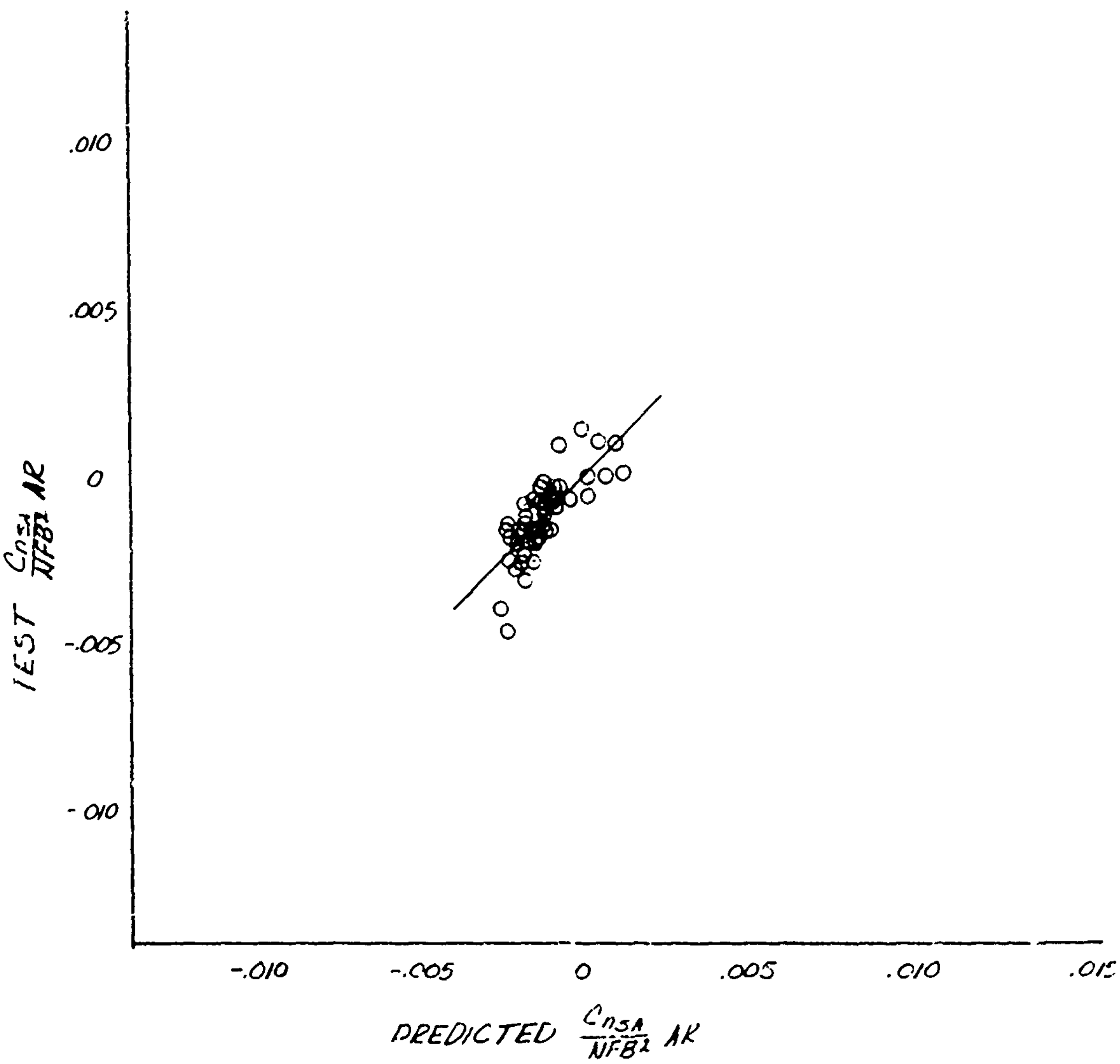
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = 16^\circ,\ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{n_{SA}}}{NFB^2} AR = .0577084 - .0006390\ell + .0021060D + .0000437C + .0000951\Delta X - .0000014\frac{SA}{FA} \times FSPD - .0020375M^2$$



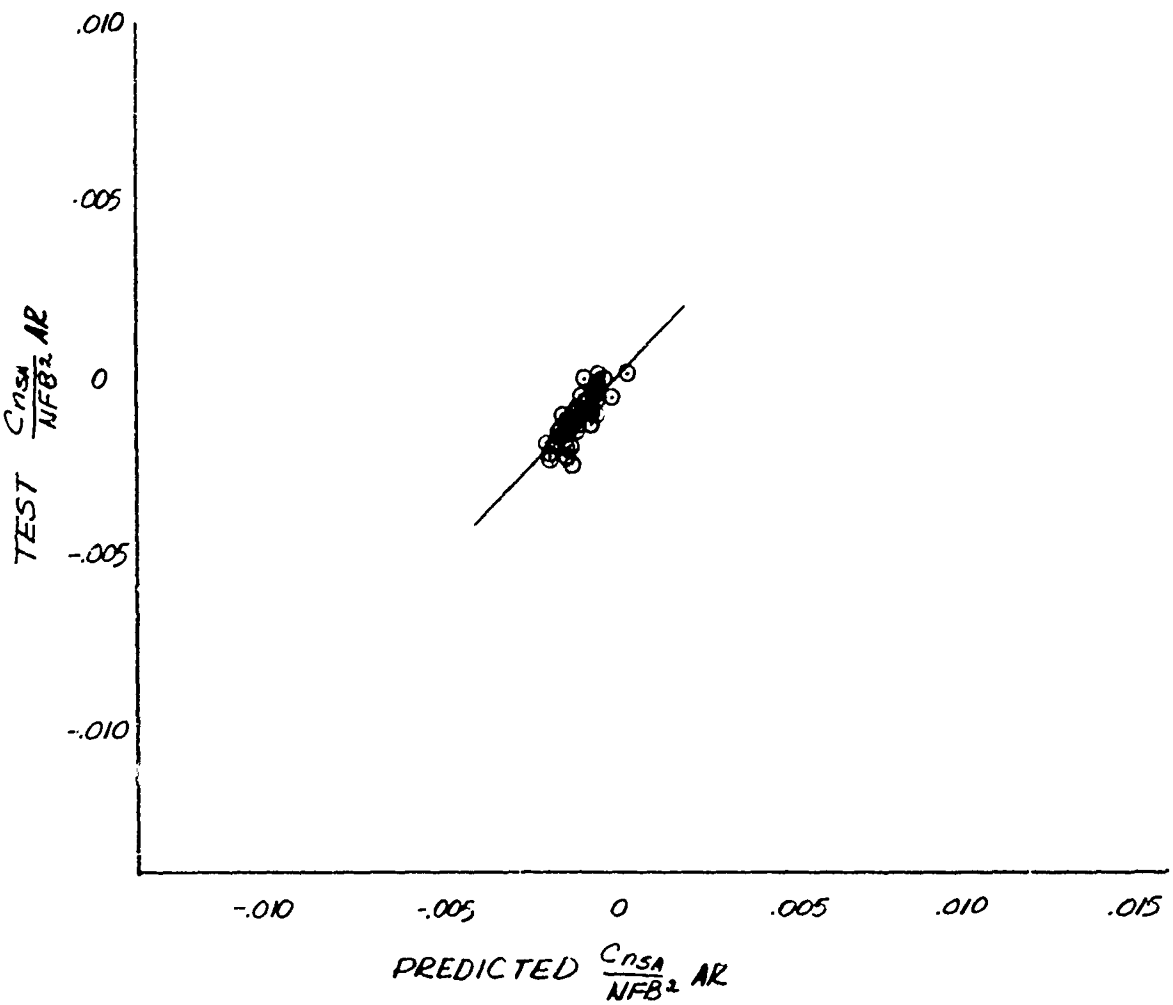
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^\circ,\ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

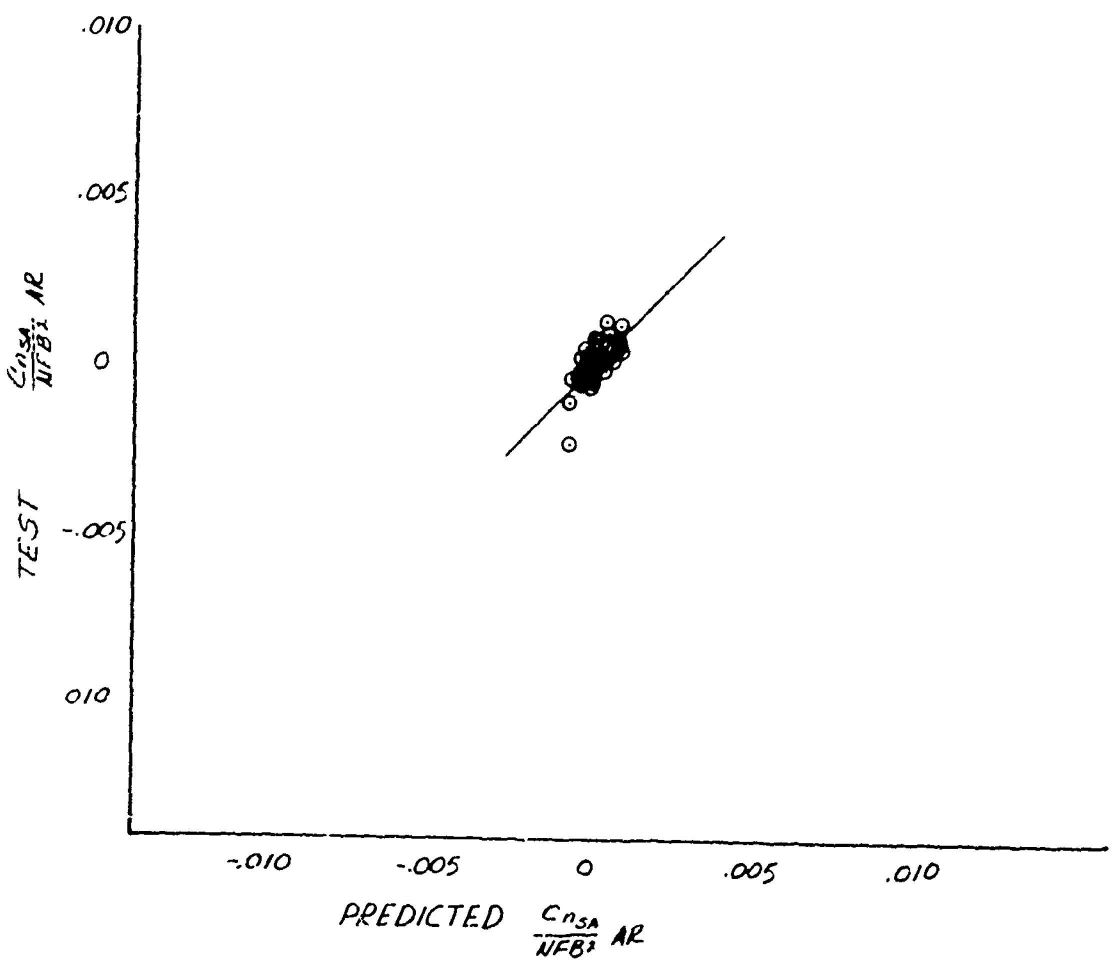
$$\frac{C_{n_{SA}}}{NFB^2} AR = .0363943 - .0004175\ell + .0014577D + .0000233C + .0000524\Delta X - 0000005\,\frac{SA}{FA} \times FSPD - .0013106M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
YAWING MOMENT COEFFICIENT

$$\alpha_{LOAD} = -4^\circ,\ \beta = 0^\circ$$
$$M = .60 - .95$$
$$\Lambda_{LE} = 16^\circ - 72.5^\circ$$

$$\frac{C_{n_{SA}}}{NFB^2} AR = .0207278 - .0002029\ell + .0006816D + .0000075C + .0000241\Delta X - .0000011 \frac{SA}{FA} \times FSPD - .0014273M^2$$



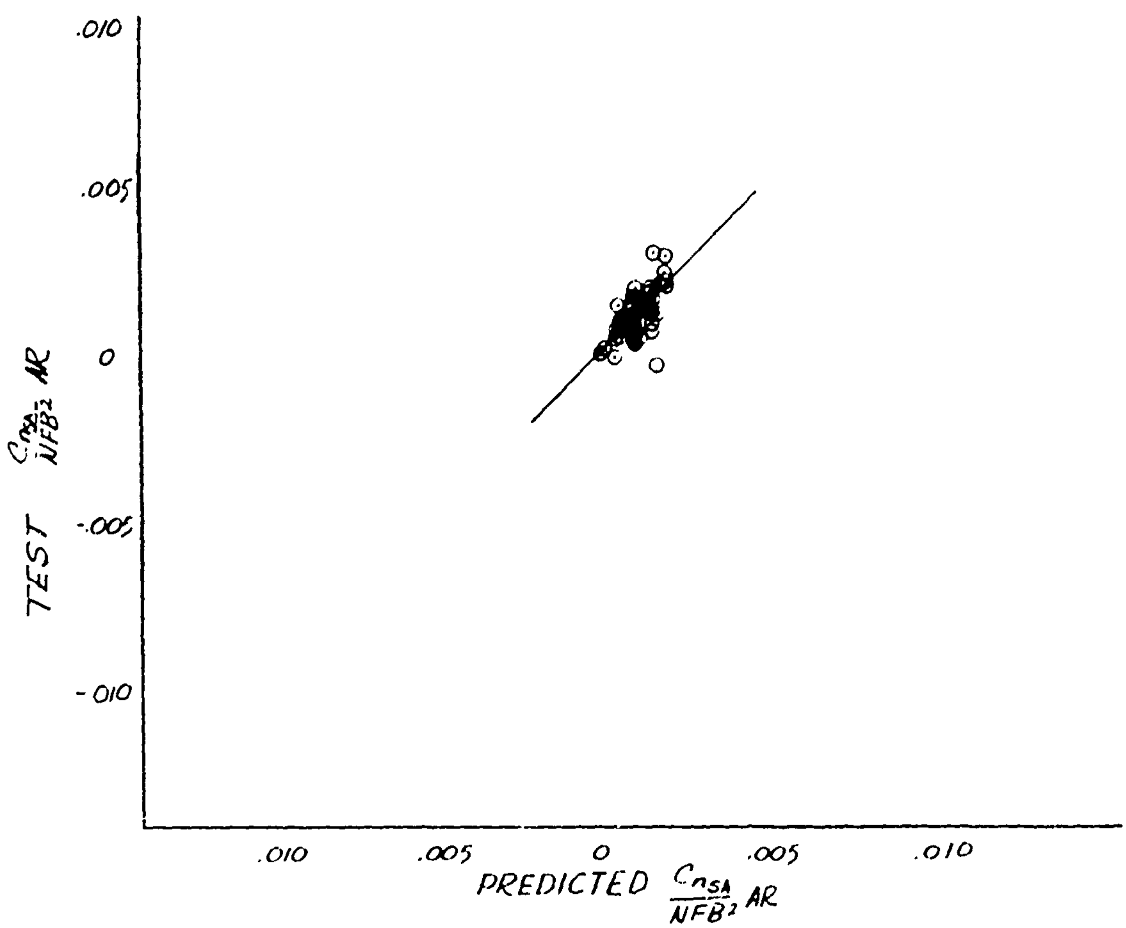
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = -9^{\circ},\ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{n_{SA}}}{NFB^2} AR = .0259114 - .0002420\,\ell + .0008334D + .0000056C + .0000188\Delta X - .0000010\,\frac{SA}{FA} \times FSPD - .0018151M^2$$



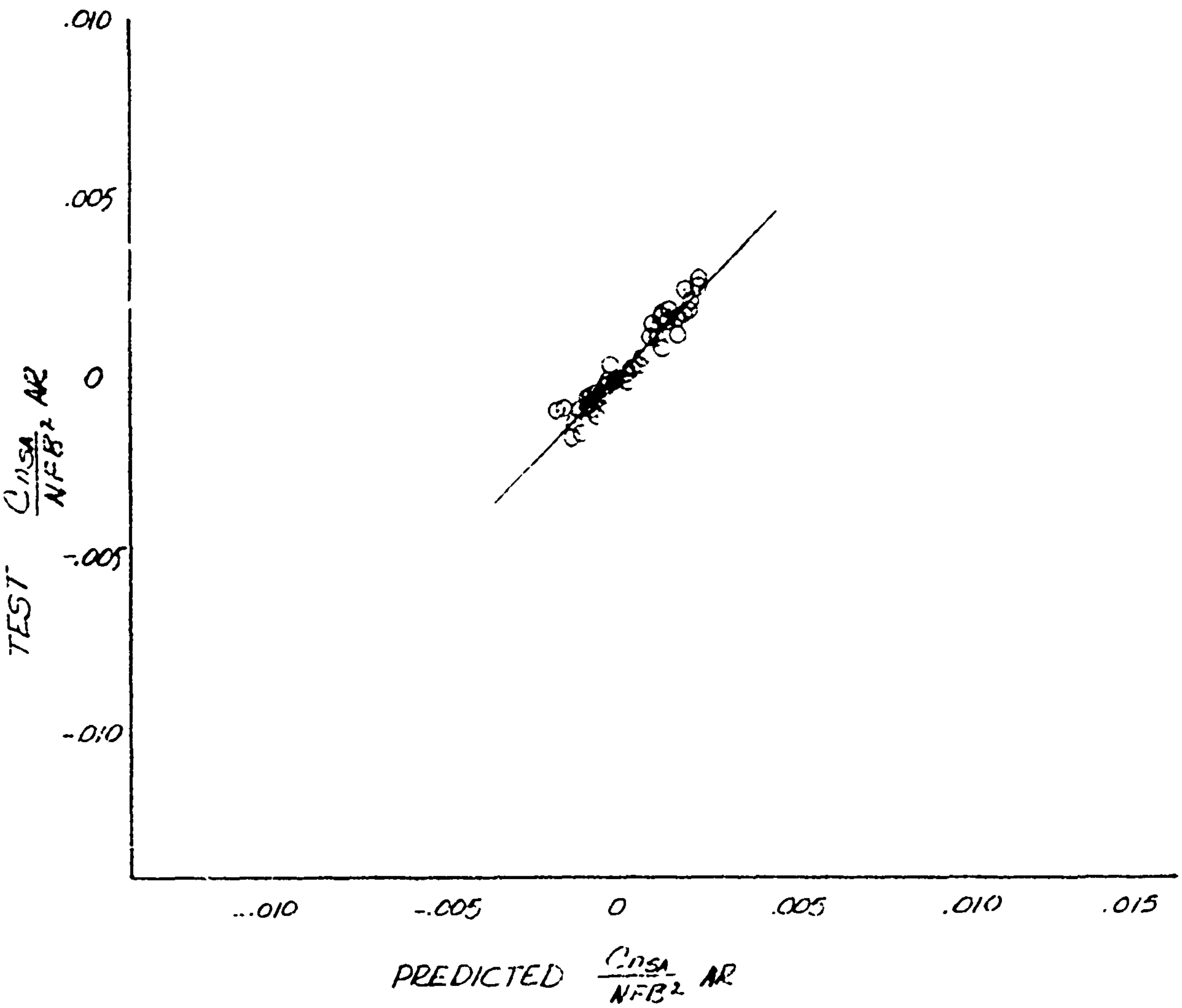
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
YAWING MOMENT COEFFICIENT

$$\alpha_{LOAD} = +6^{\circ},\ \beta = +10^{\circ}$$

$$M = .60 - .95$$

$$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$$

$$\frac{C_{n_{SA}}}{NFB^2} AR = .0864733 - .0010495\ell + .0039743D + .0000518C + .0001269\Delta X + .0000003 \frac{SA}{FA} \times FSPD - .0008079M^2$$



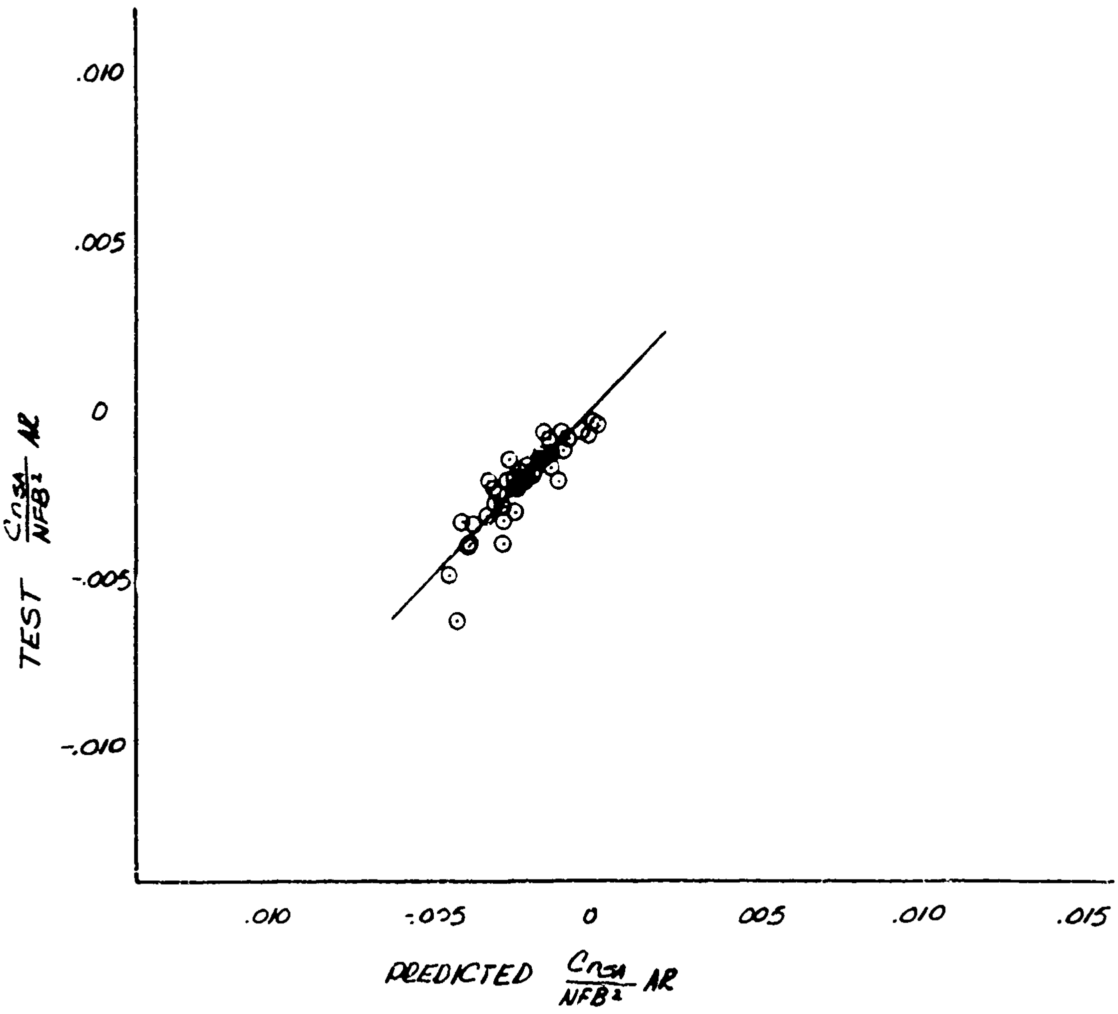
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^\circ,\ \beta = -10^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

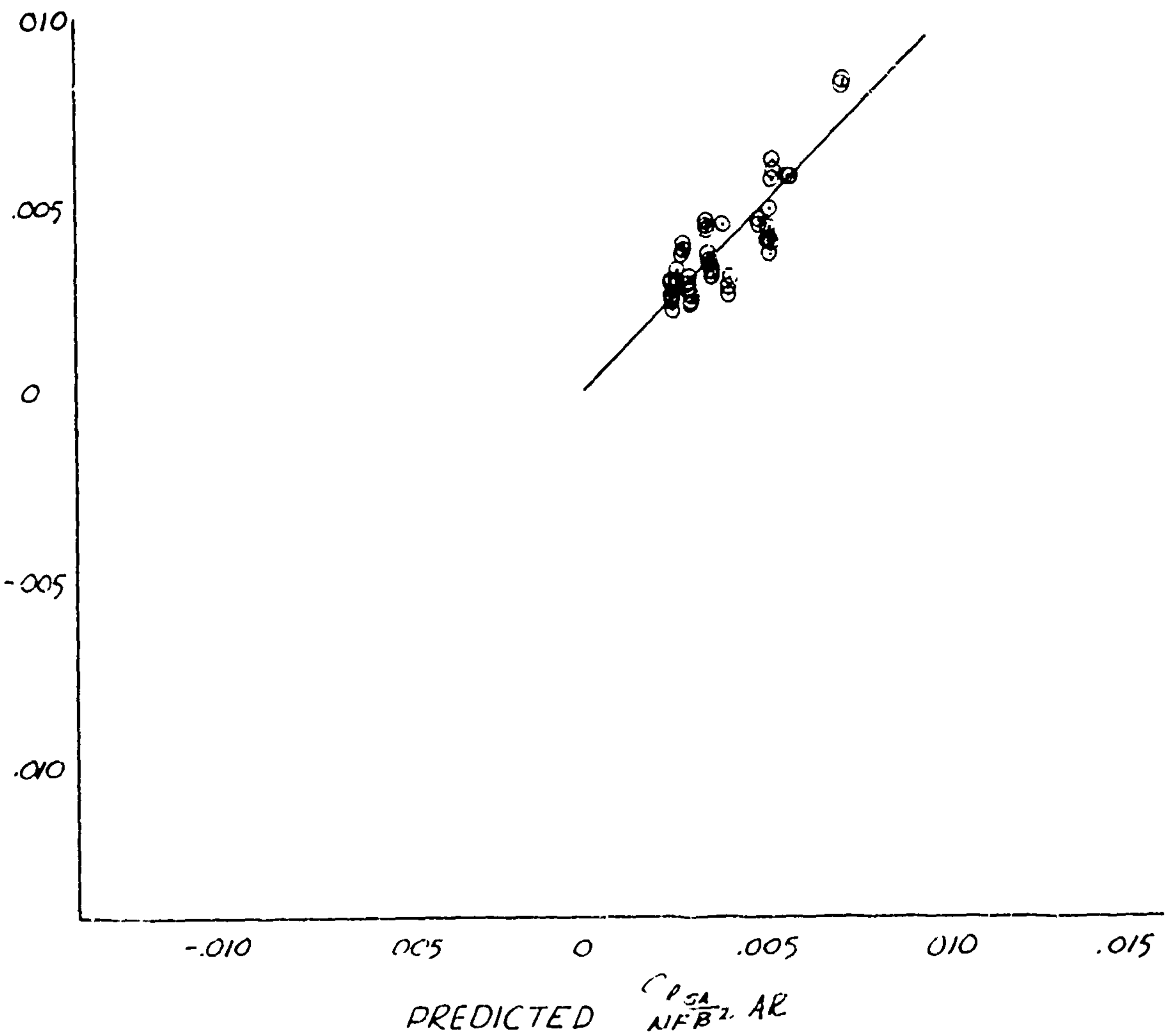
$$\frac{C_{n_{SA}}}{NFB^2} AR = -.0008678 + .0000949\ell - .0006516D - .0000025C - .0000173\Lambda X - .0000021 \frac{SA}{FA} \times FSPD - .0021274M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
ROLLING MOMENT COEFFICIENT

$\alpha_{LOAD} = 16^{o}, \ \beta = 0^{o}$
$M = .60 - .95$
$\Lambda_{LE} = 16^{o} - 72.5^{o}$

$$\frac{C_{\ell_{SA}}}{NFB^2} AR = -.0936017 + .0007323\ell - .0018417D + .0000395C + .0000479\Delta X + .0000021 \frac{SA}{FA} \times FSPD + .0000335M^2$$



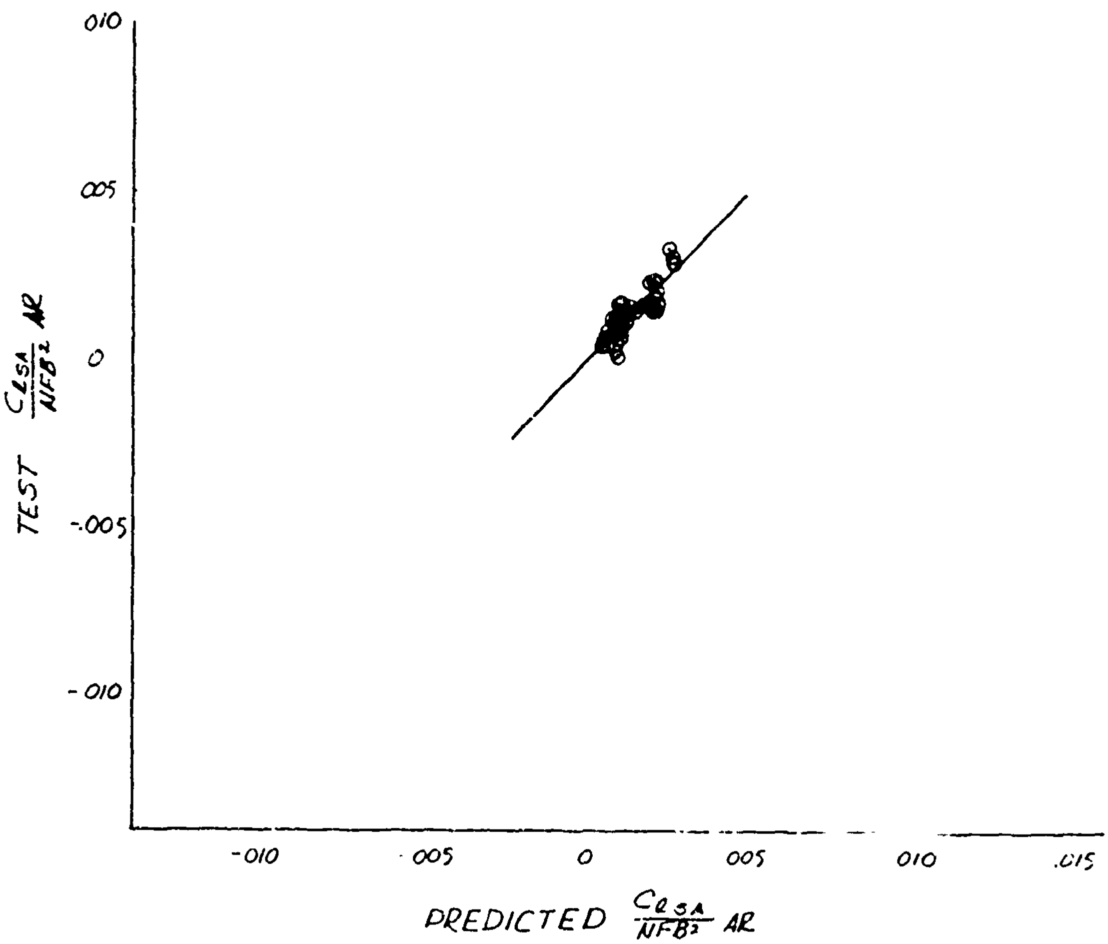
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
ROLLING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^\circ,\ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{IE} = 16^\circ - 72.5^\circ$

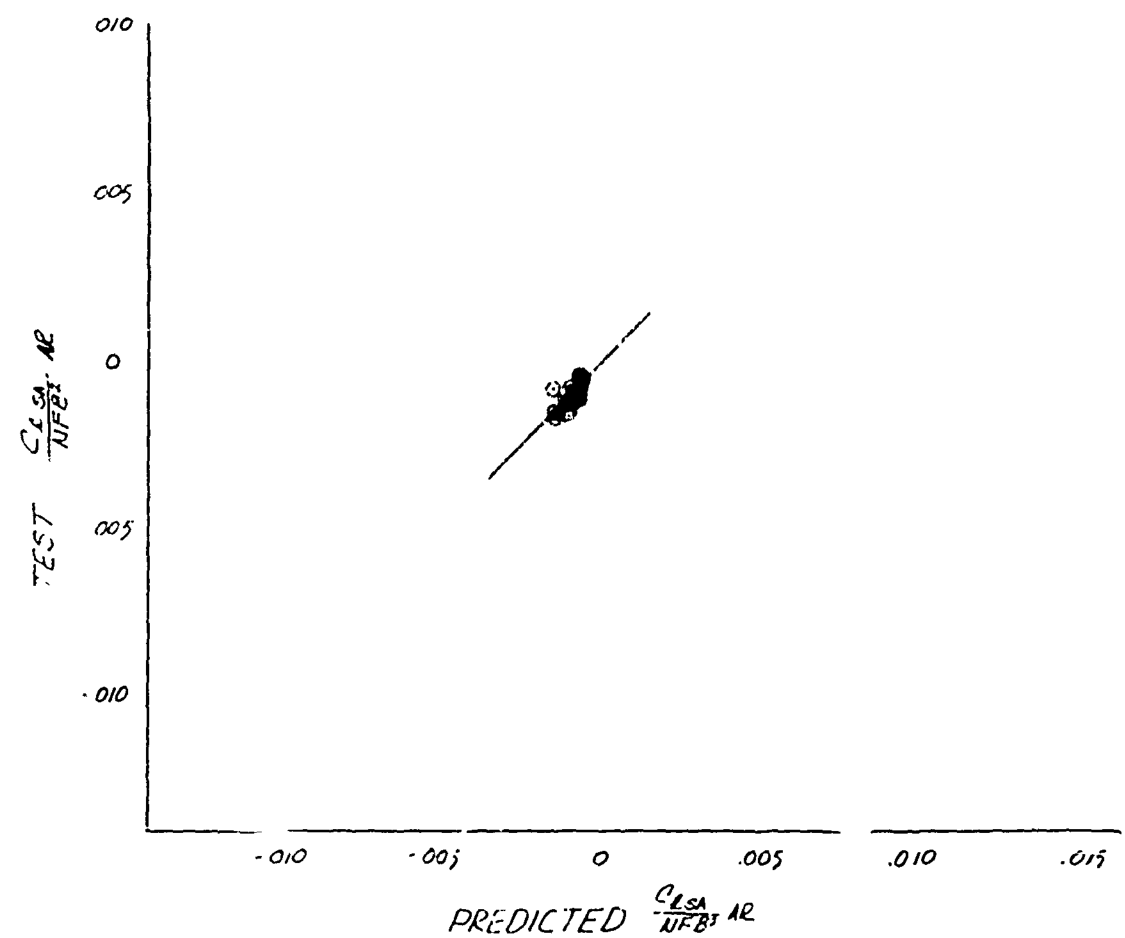
$$\frac{C_{\ell_{SA}}}{NFB^2}\ AR = -.0484171 + .0003806\,\ell - .0009682D + .0000171C + .00002717\Delta X + .0000009\ \frac{SA}{FA} \times FSPD - .0003218M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
ROLLING MOMENT COEFFICIENT

$$\alpha_{LOAD} = -4^\circ, \ \beta = 0^\circ$$
$$M = .60 - .95$$
$$\Lambda_{LE} = 16^\circ - 72.5^\circ$$

$$\frac{C_{\ell SA}}{NFB^2} AR = -.0067555 + .0000330\,\ell - .0000500D + .0000030C + .0000119\Delta X + .0000004\,\frac{SA}{FA} \times FSPD + .0000193M^2$$



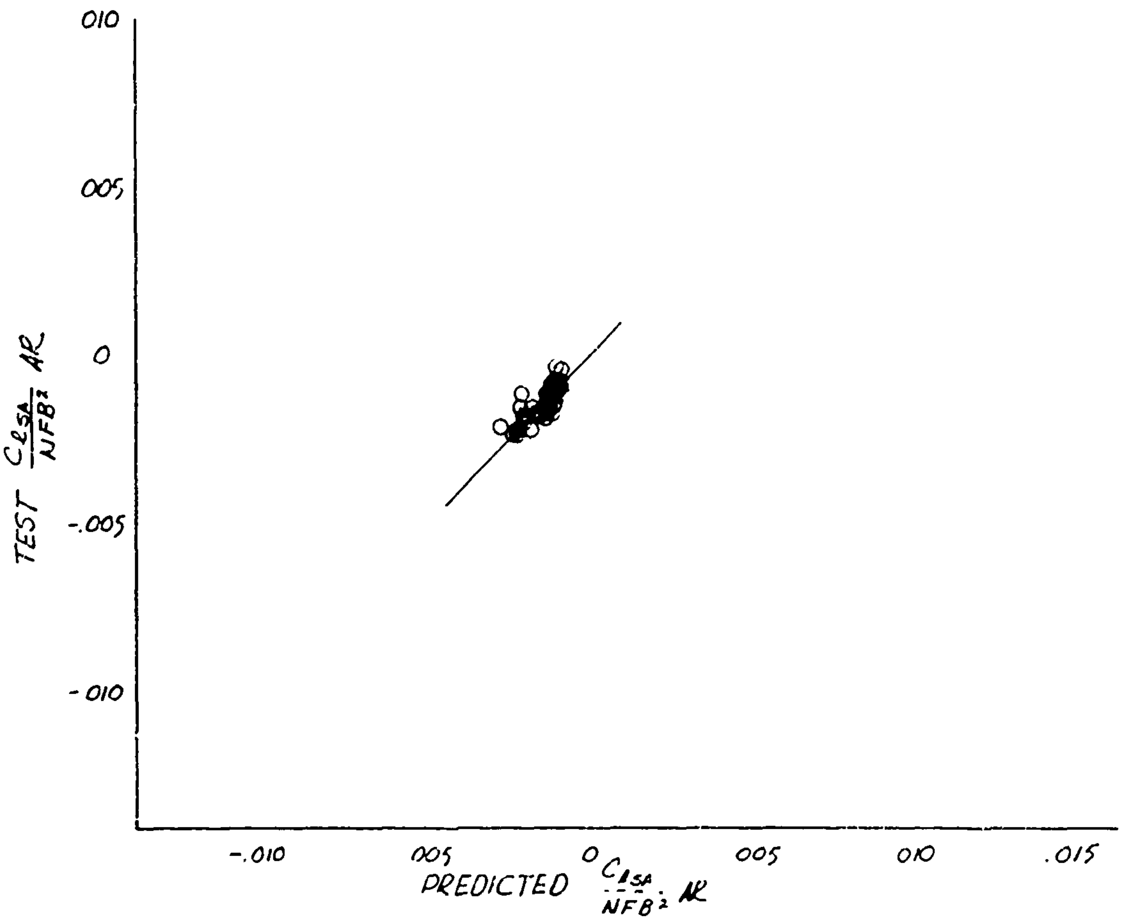
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
ROLLING MOMENT COEFFICIENT

$\alpha_{LOAD} = -9^{\circ}, \quad = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72\ 5^{\circ}$

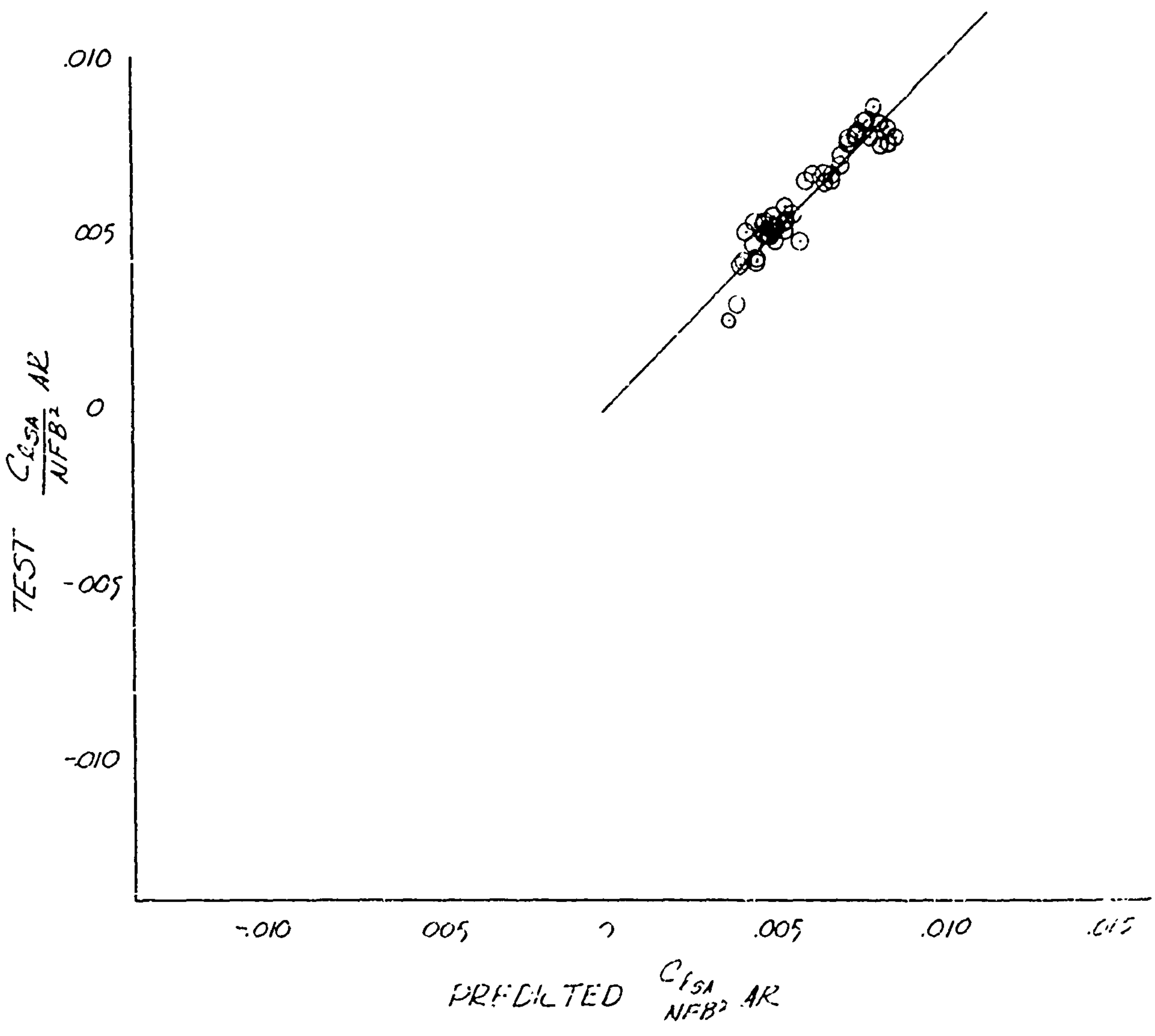
$$\frac{C_{\ell_{SA}}}{NFB^2} AR = .0116152 - .0001304\,\ell + .0004534D - .0000023C + .0000117\Delta X - .0000001\,\frac{SA}{FA} \times FSPD + .0001654M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
ROLLING MOMENT COEFFICIENT

$$\alpha_{LOAD} = +6^\circ,\ \beta = +10^\circ$$
$$M = .60 - .95$$
$$\Lambda_{LE} = 16^\circ - 72.5^\circ$$

$$\frac{C_{\ell_{SA}}}{NFB^2} AR = -.1115689 + .0008846\,\ell - .0020837D + .0000230C + .0000571\Delta X + .0000022\,\frac{SA}{FA} \times FSPD + .000950M^2$$



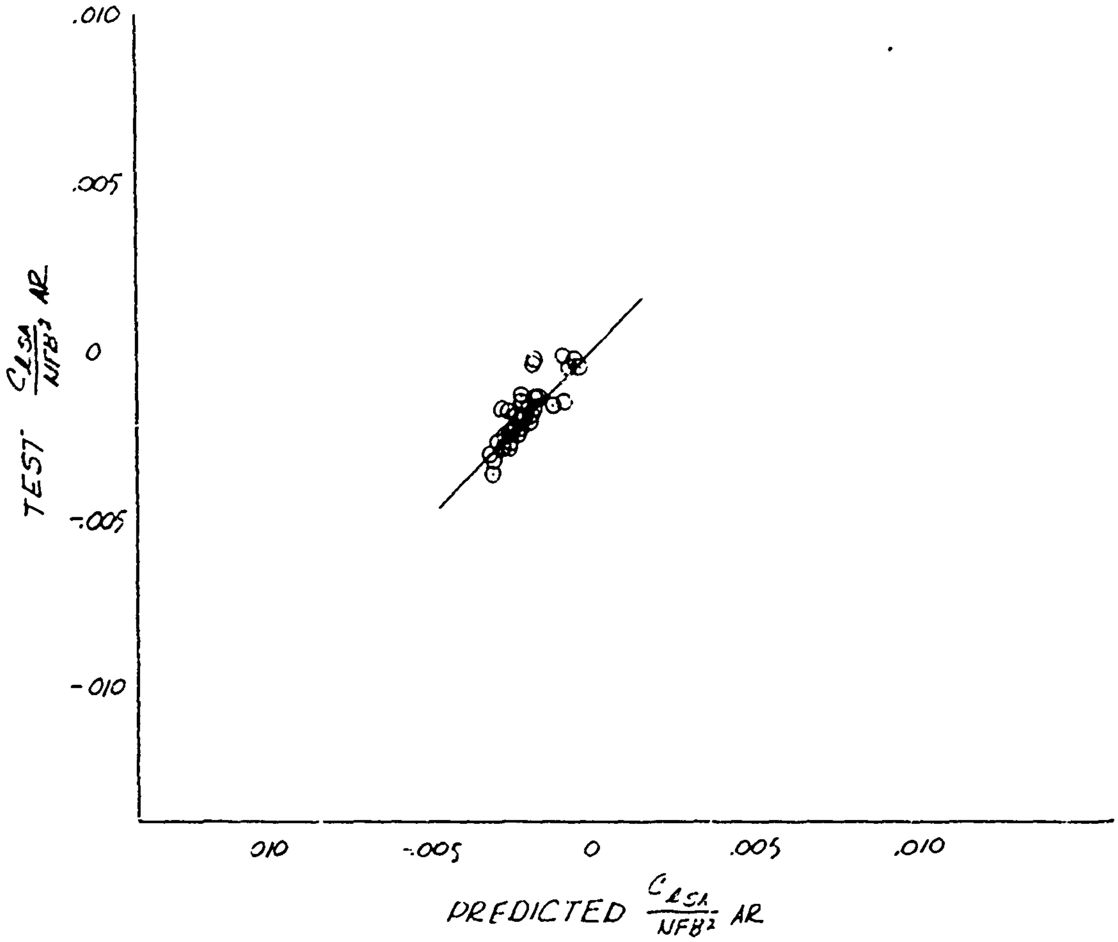
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK + PYLON
Outboard
ROLLING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^\circ, \beta = -10^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{\ell SA}}{NFB^2} AR = -.0081651 + .0000391\ell - .0001567D + .0000188C + .0000143dX + .0000003 \frac{SA}{FA} \times FSPD - .0012870M^2$$



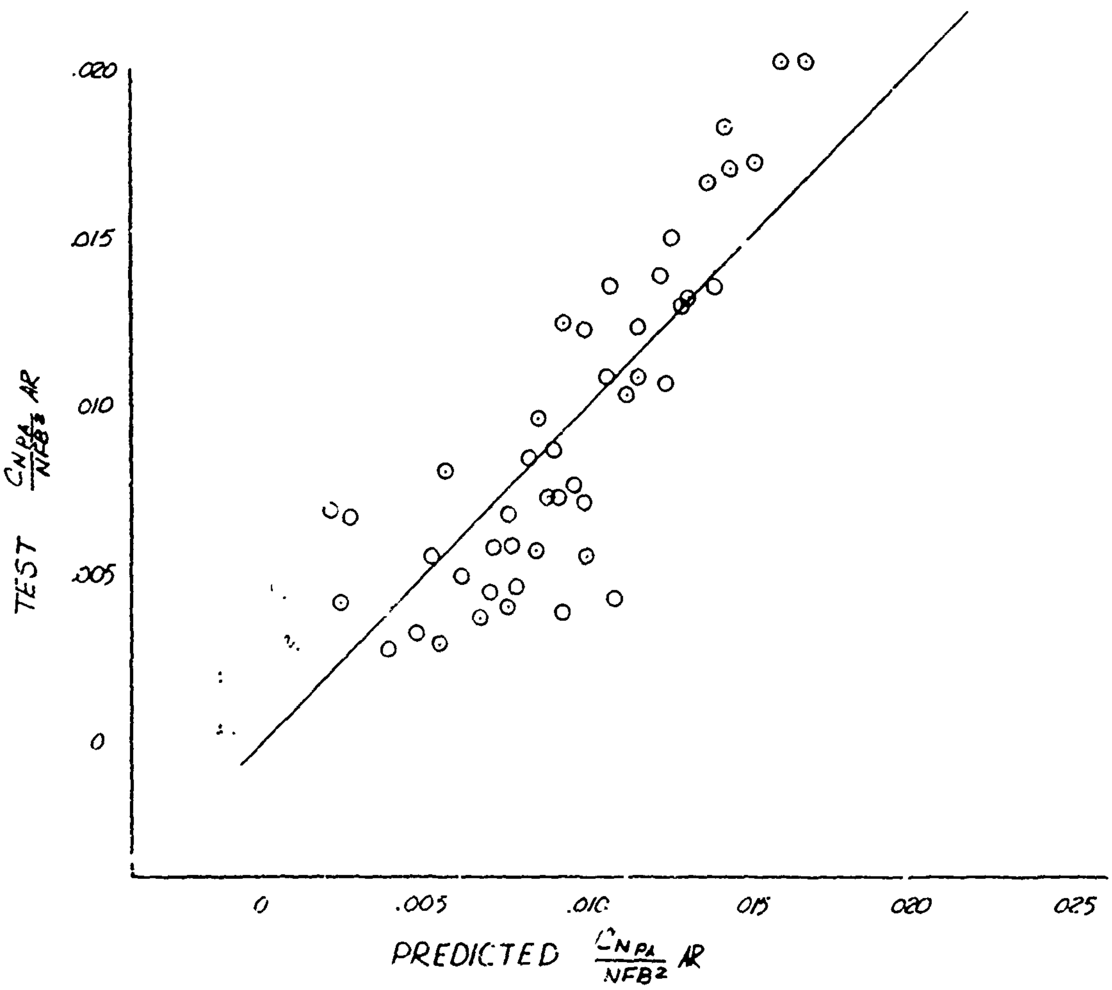
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = 16^\circ,\ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{N_{PA}}}{NFB^2} AR = -.0987691 + .0005441\ell + .0002258D + .0000224C + .0001206\Delta X + .0000059 \frac{PA}{FA} \times FSPD - .0055904M^2$$



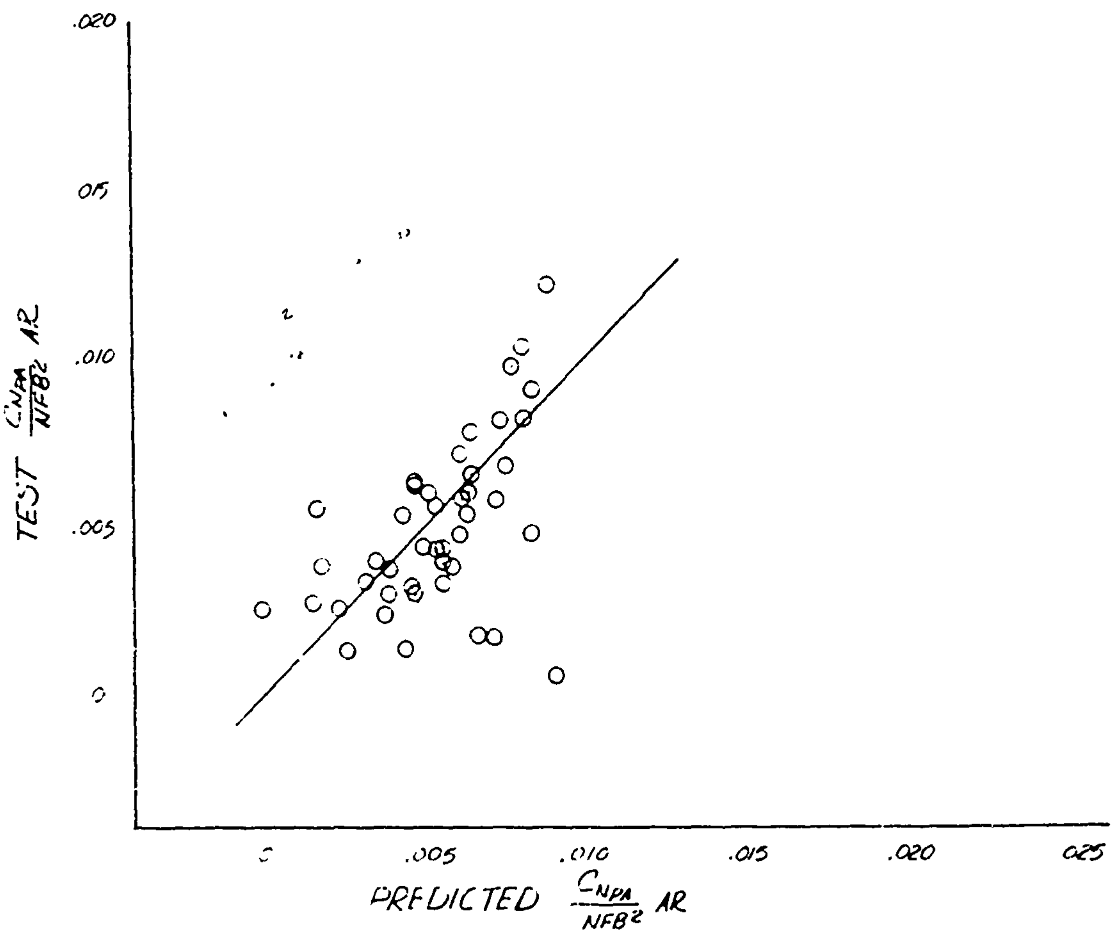
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = 6^\circ,\ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{N_{PA}}}{NFB^2} AR = -.0290420 + .0001833\,\ell - .0000561D - .0000121C + .0001315\Delta X + .0000010\,\frac{PA}{FA} \times FSPD + .0064087M^2$$



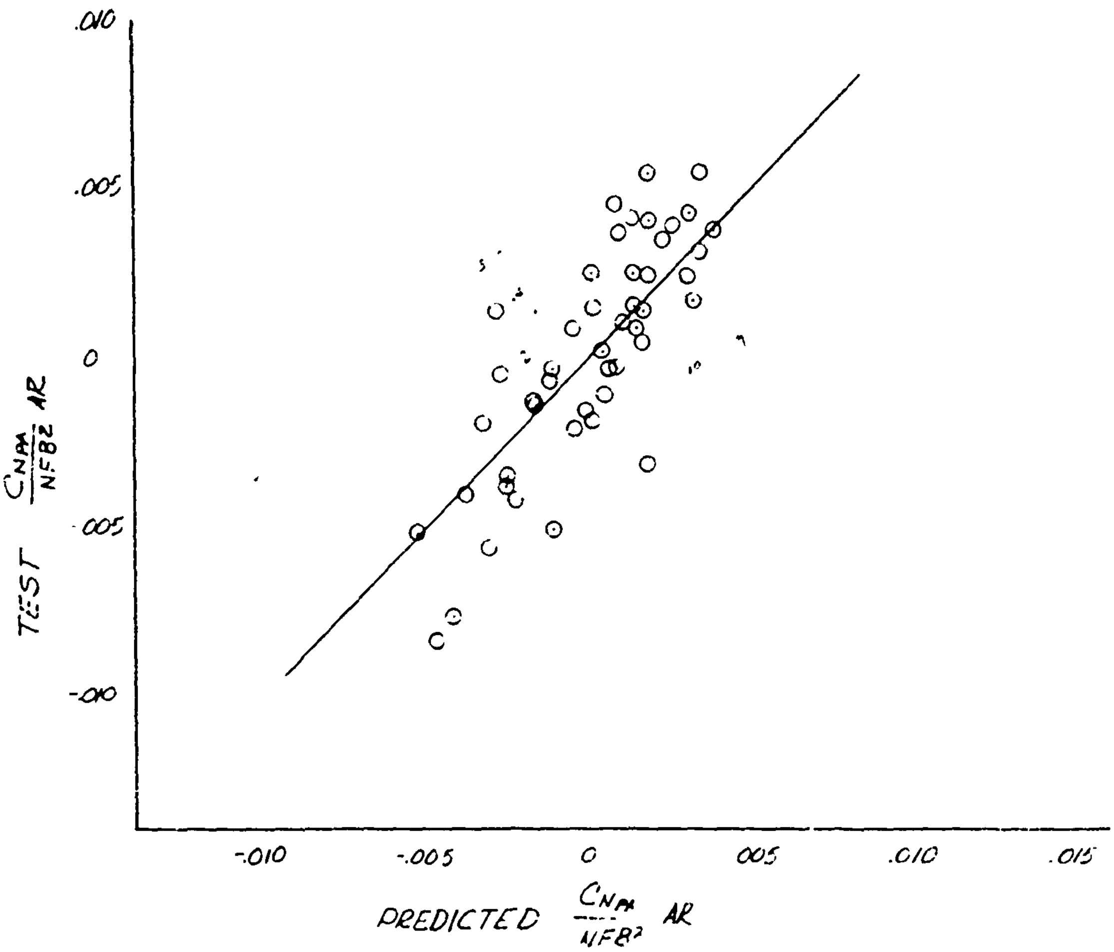
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = -4^\circ,\ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{N_{PA}}}{NFB^2} AR = .0757537 - .0002127\,\ell - .0006255D - .0000792C - .0001333\Delta X - .0000082\,\frac{PA}{FA} \times FSPD - .0054677M^2$$



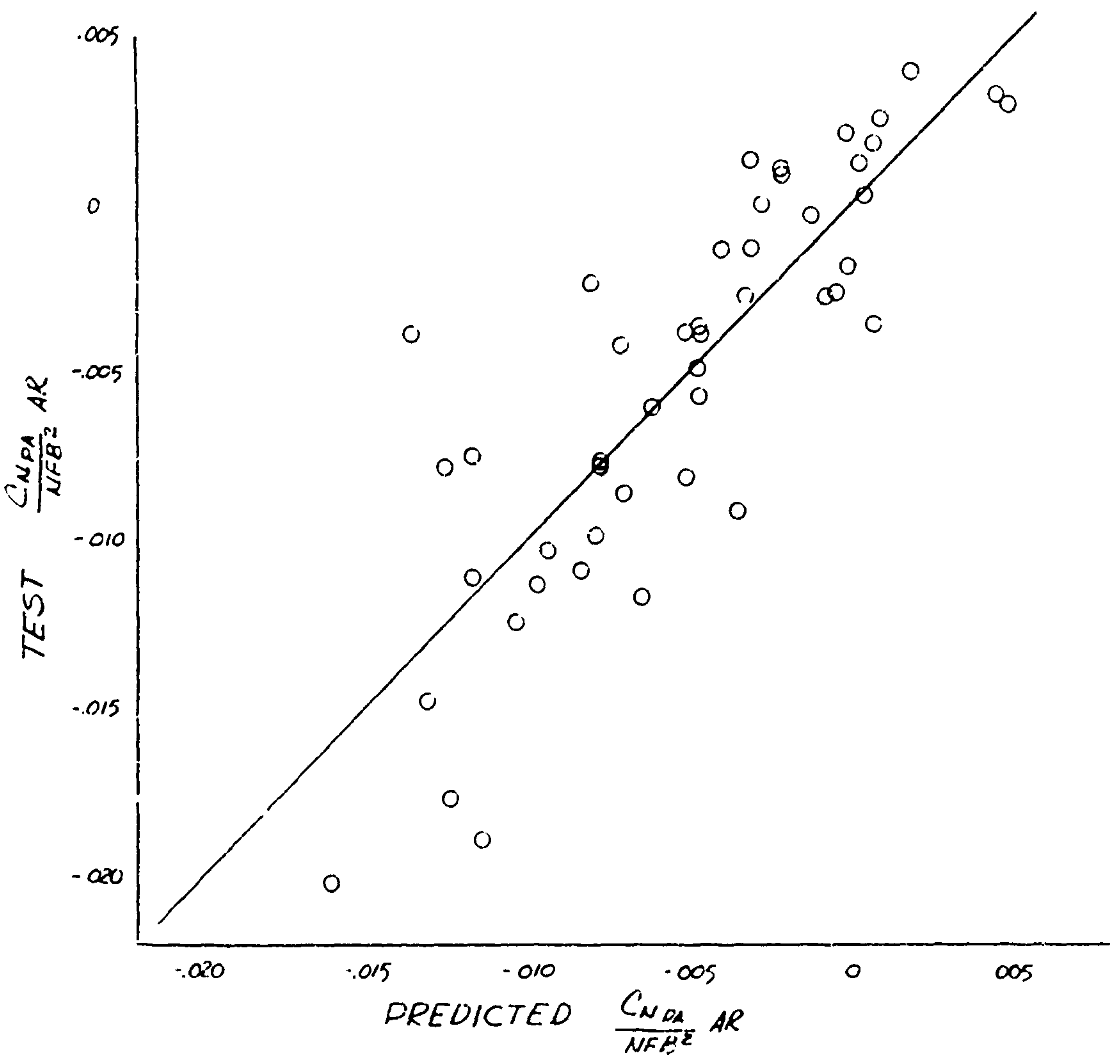
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = -9^{o}$, $\beta = 0^{o}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{o} - 72.5^{o}$

$$\frac{C_{N_{PA}}}{NFB^2} AR = .1151453 - .0003915\ell - .0002011D - .0001404C - .0001951\Delta X - .0000134 \frac{PA}{FA} \times FSPL - .0176062M^2$$



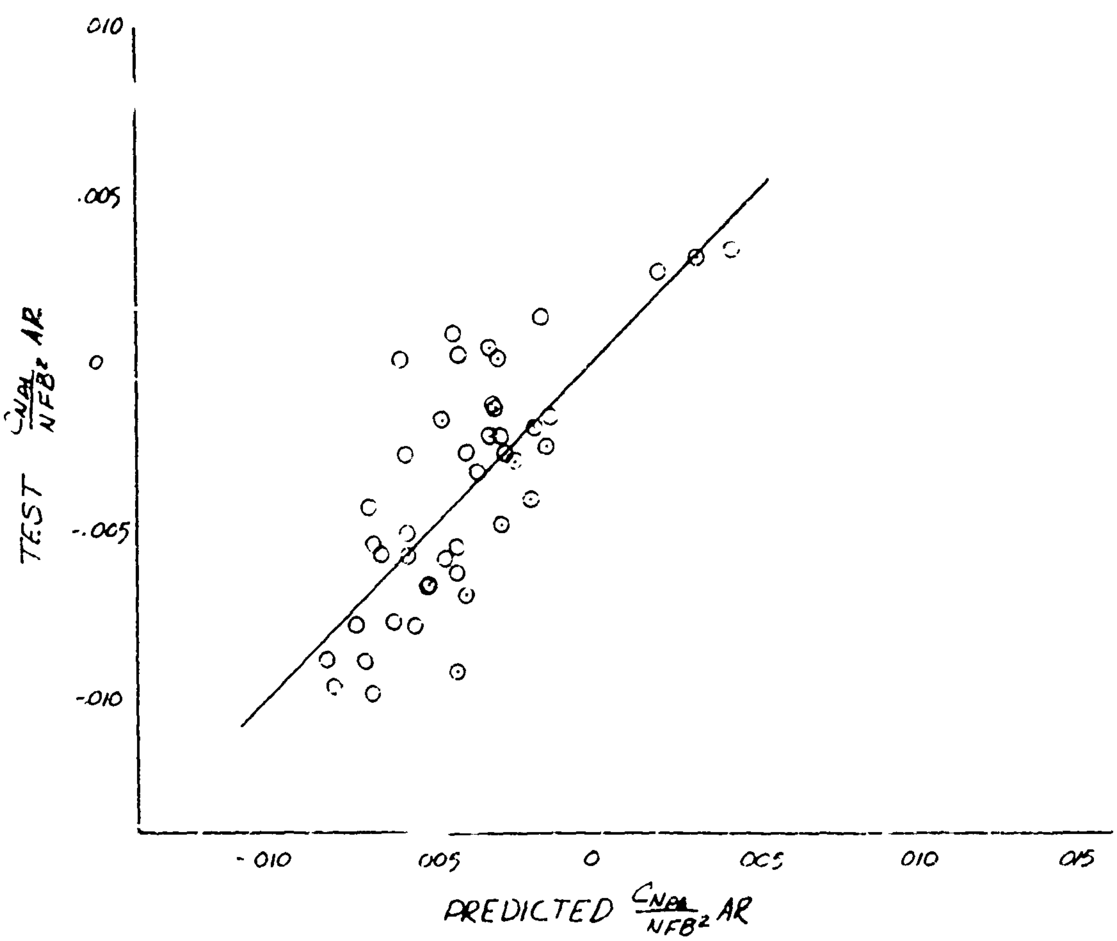
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = 6^\circ, \ \beta = +10^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{N_{PA}}}{NFB^2} AR = .1851928 - .0016444\,\ell + .0041495D + .0000491C + .0000960\Delta X - .0000055\,\frac{PA}{FA} \times FSPD + .0042048M^2$$



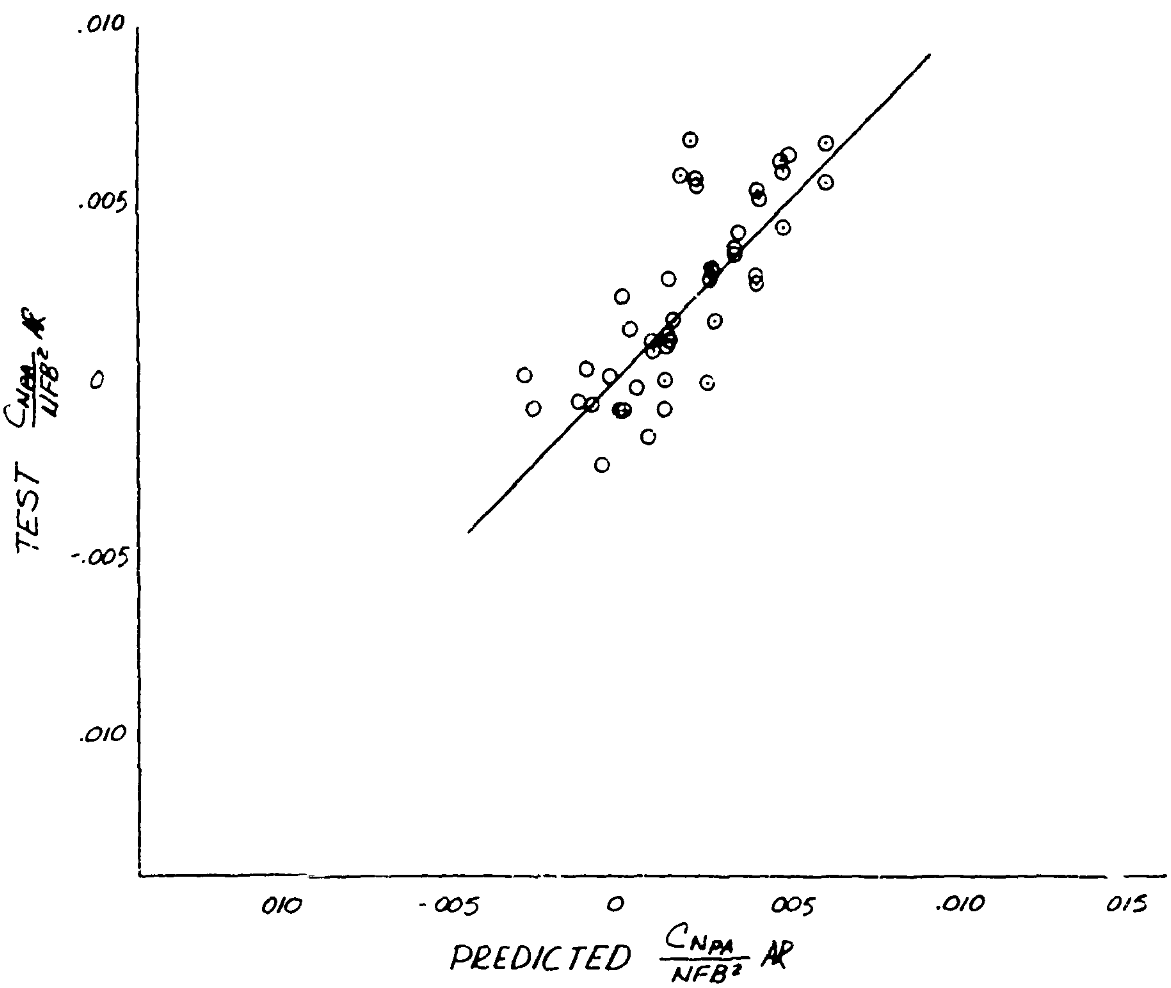
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
NORMAL FORCE COEFFICIENT

$\alpha_{LOAD} = 6^\circ, \beta = -10^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{N_{PA}}}{NFB^2} AR = -.1185786 + .0012230\ell - .0039128D - .0000521C$$
$$-.0000725\ell X - .0000035 \frac{PA}{FA} \times FSPD + .0048059M^2$$



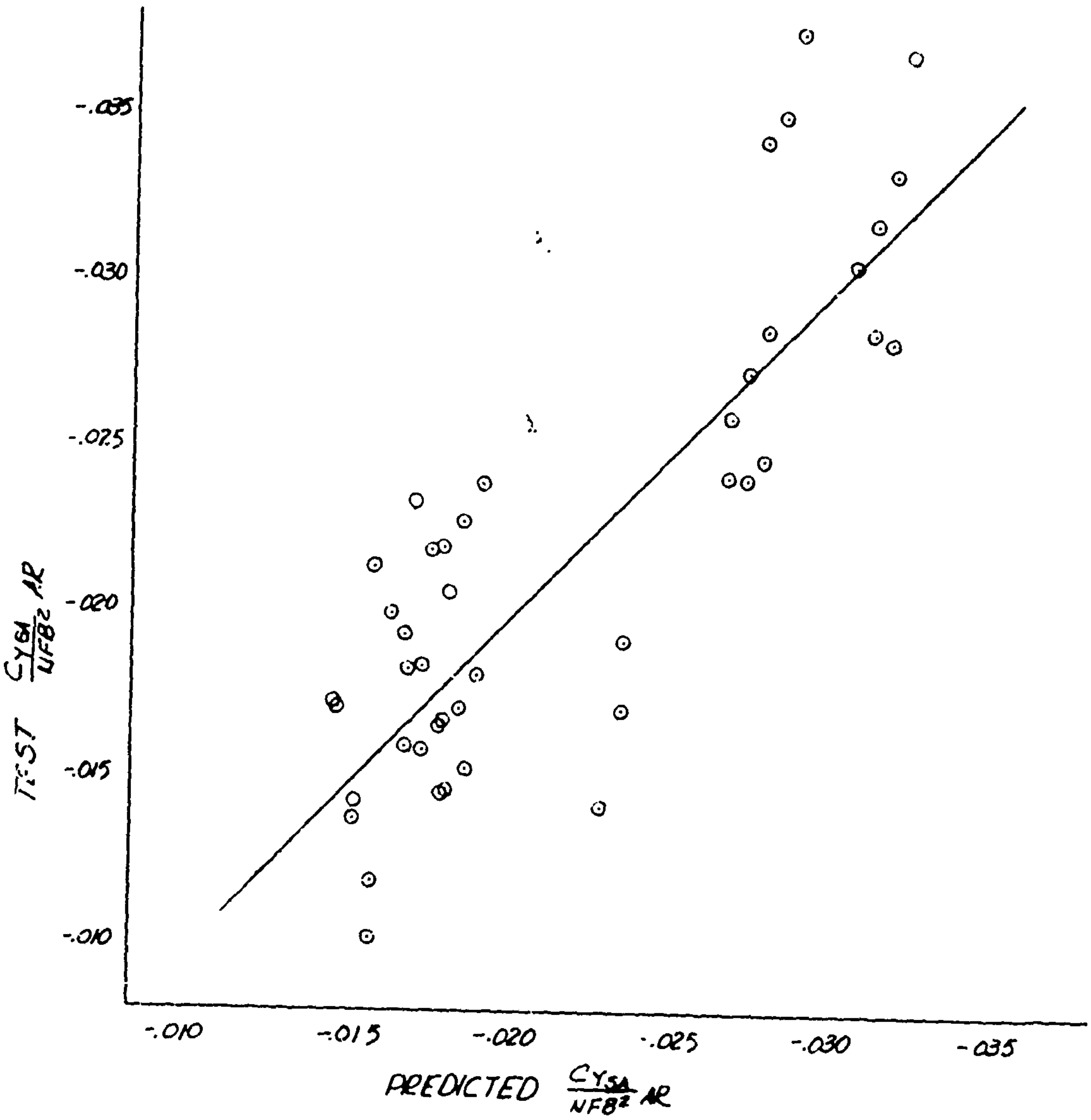
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = 16^\circ,\ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = 3143940 - .0024341\ell + .0063170D - .0002141C - .0002896\Delta X - .0000046 \frac{SA}{FA} \times FSPD - .0020471M^2$$



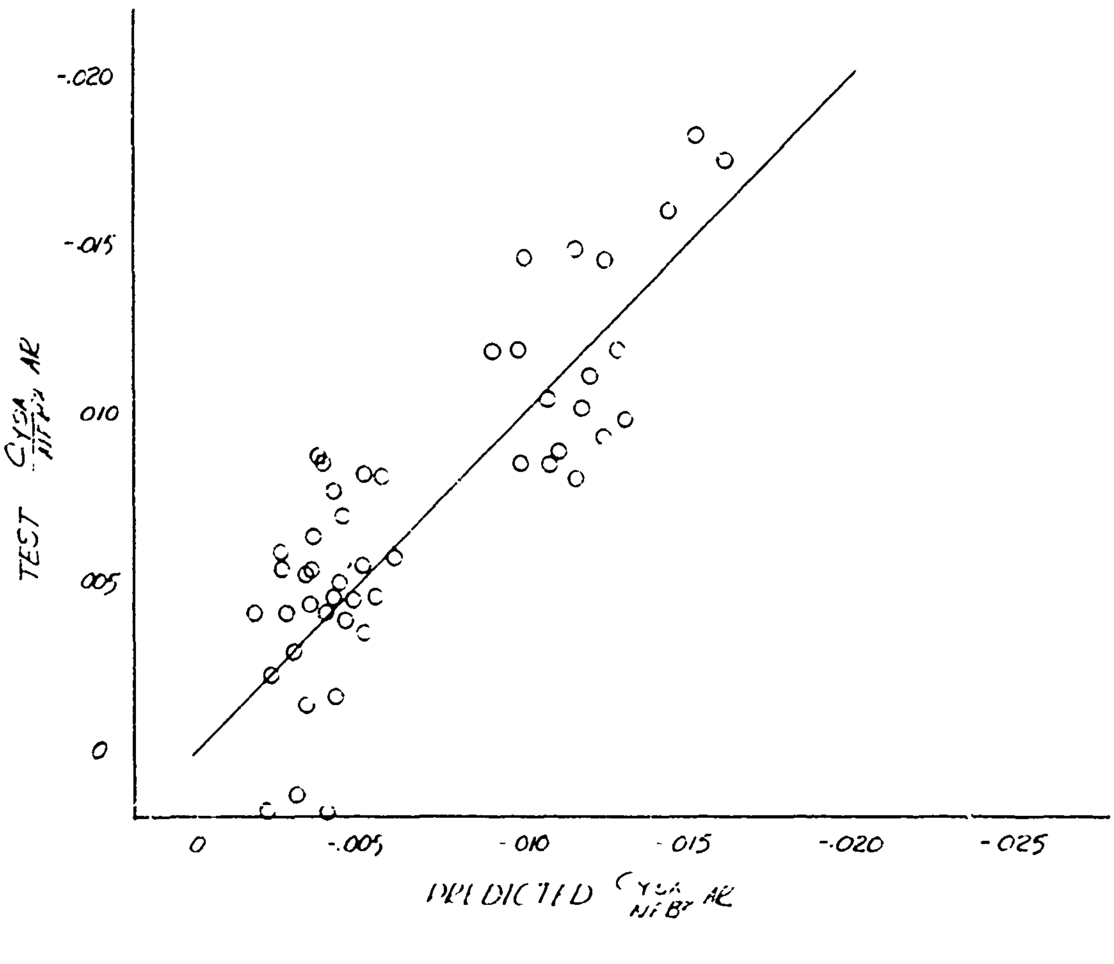
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = .2126746 - .00151117\ell + .0034772D - .0001422C - .0002806\Delta X - .0000013 \frac{SA}{FA} \times FSPD + .0032703M^2$$



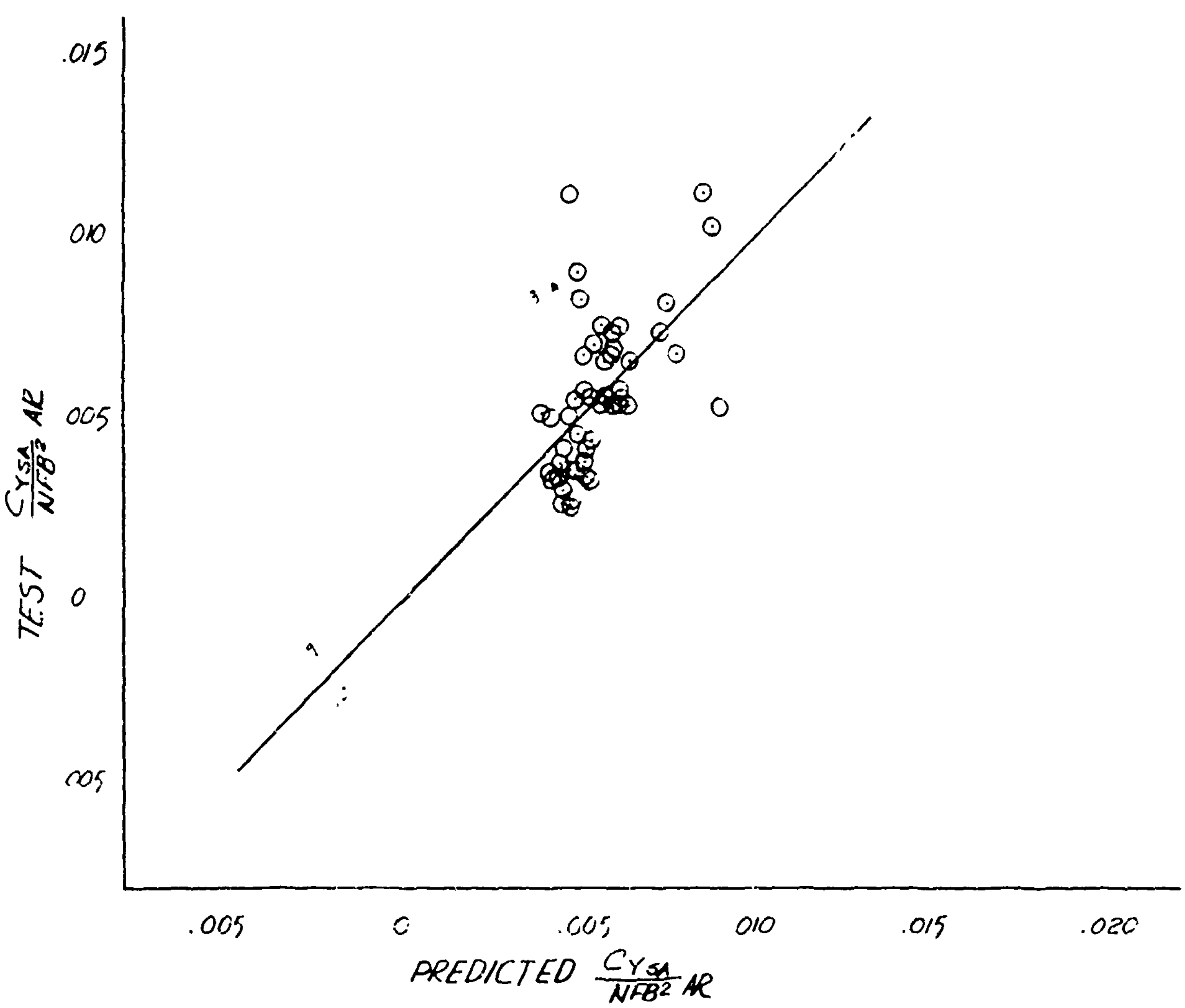
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = -4^\circ,\ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = -.0443961 + .0005617\ell - .0019807D - .0000216C - .0000967\Delta X + .0000002\,\frac{SA}{FA} \times FSPD + .0008805M^2$$



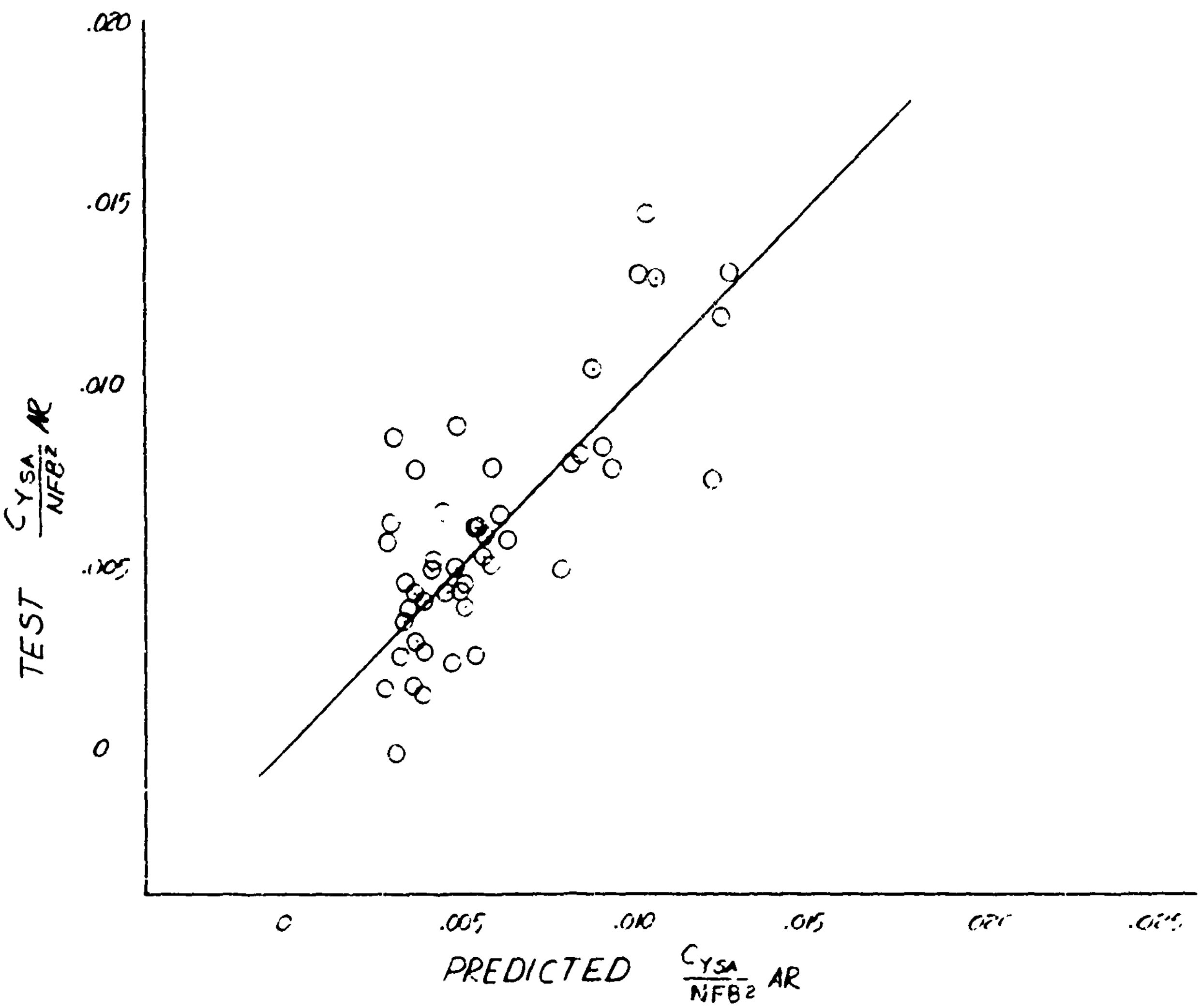
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = -9^{\circ},\ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = -.0853632 + .0009737\ell - .0034294D - .0000118C - .0001663\Delta X + .0000038 \frac{SA}{FA} \times FSPD - .0009149M^2$$



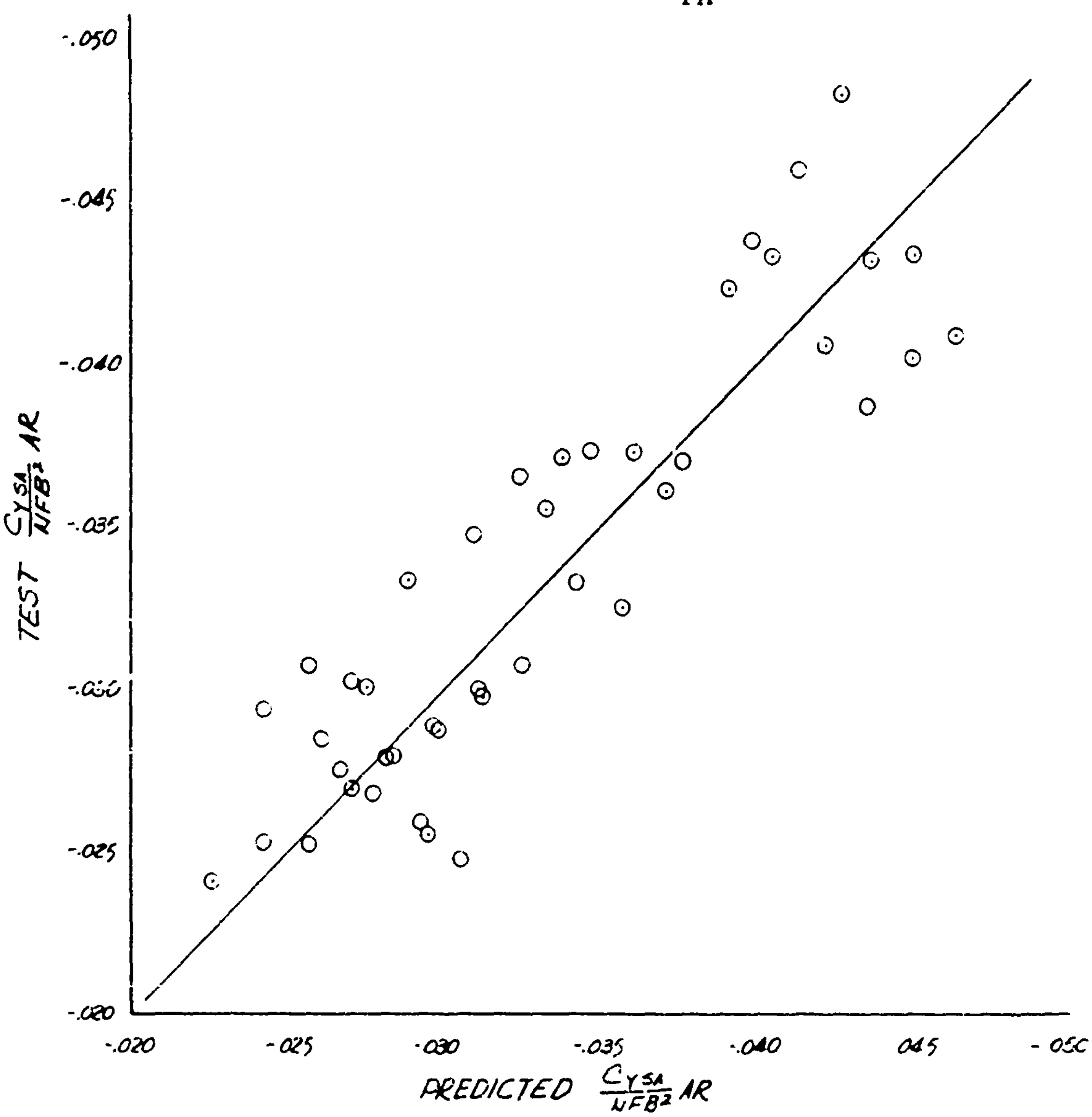
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \beta = +10^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = .4188619 - .00326820\ell + .0073149D - .0001224C - .00036714X - .0000037 \frac{SA}{FA} \times FSPD - .0052403M^2$$



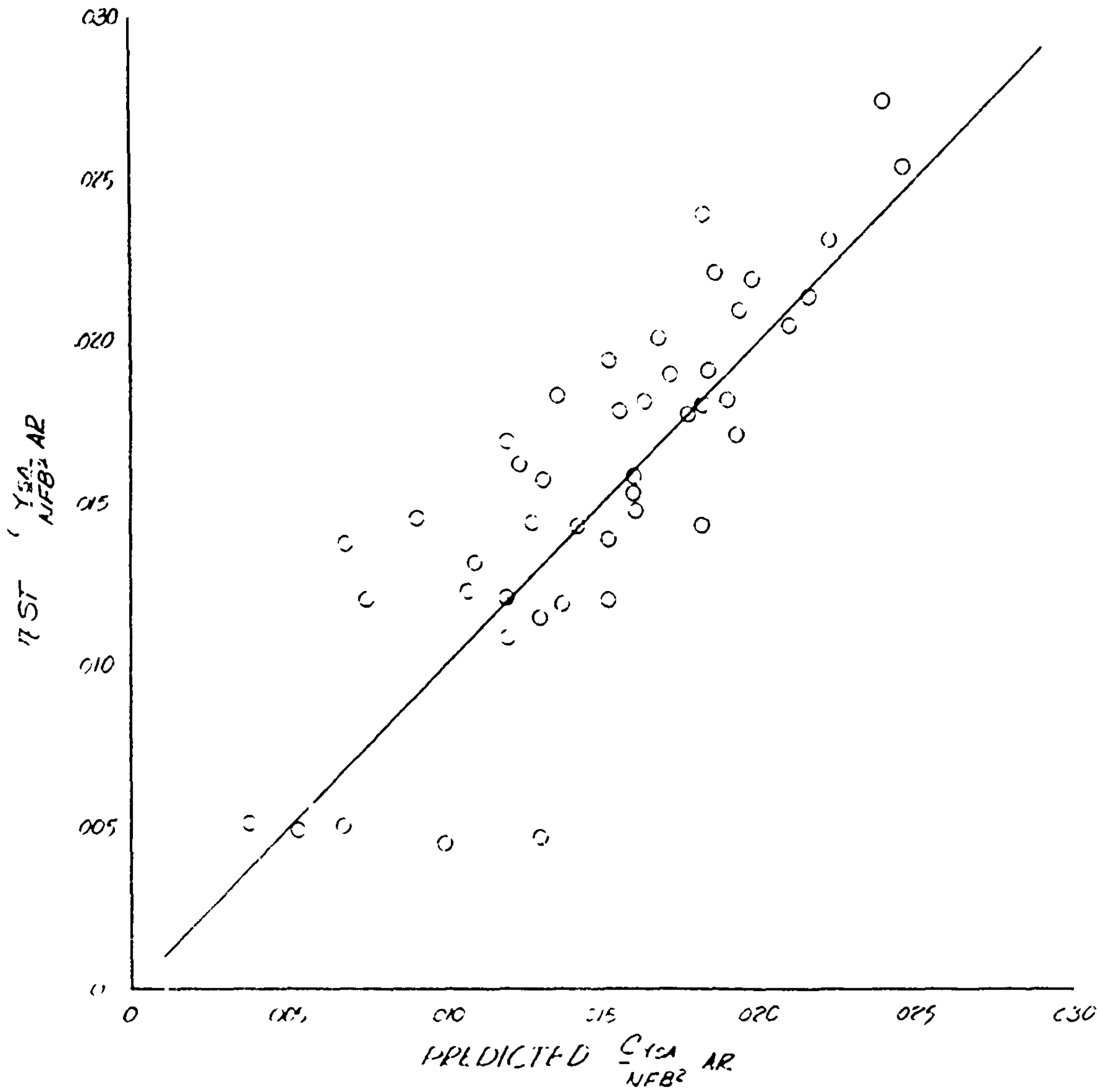
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
SIDE FORCE COEFFICIENT

$\alpha_{LOAD} = 6^\circ,\ \beta = -10^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{Y_{SA}}}{NFB^2} AR = -.2097369 + .0018156\ell - .0042758D - .0000765C - .0001195\Delta X + 0000109 \frac{SA}{FA} \times FSPD + .0115524M^2$$



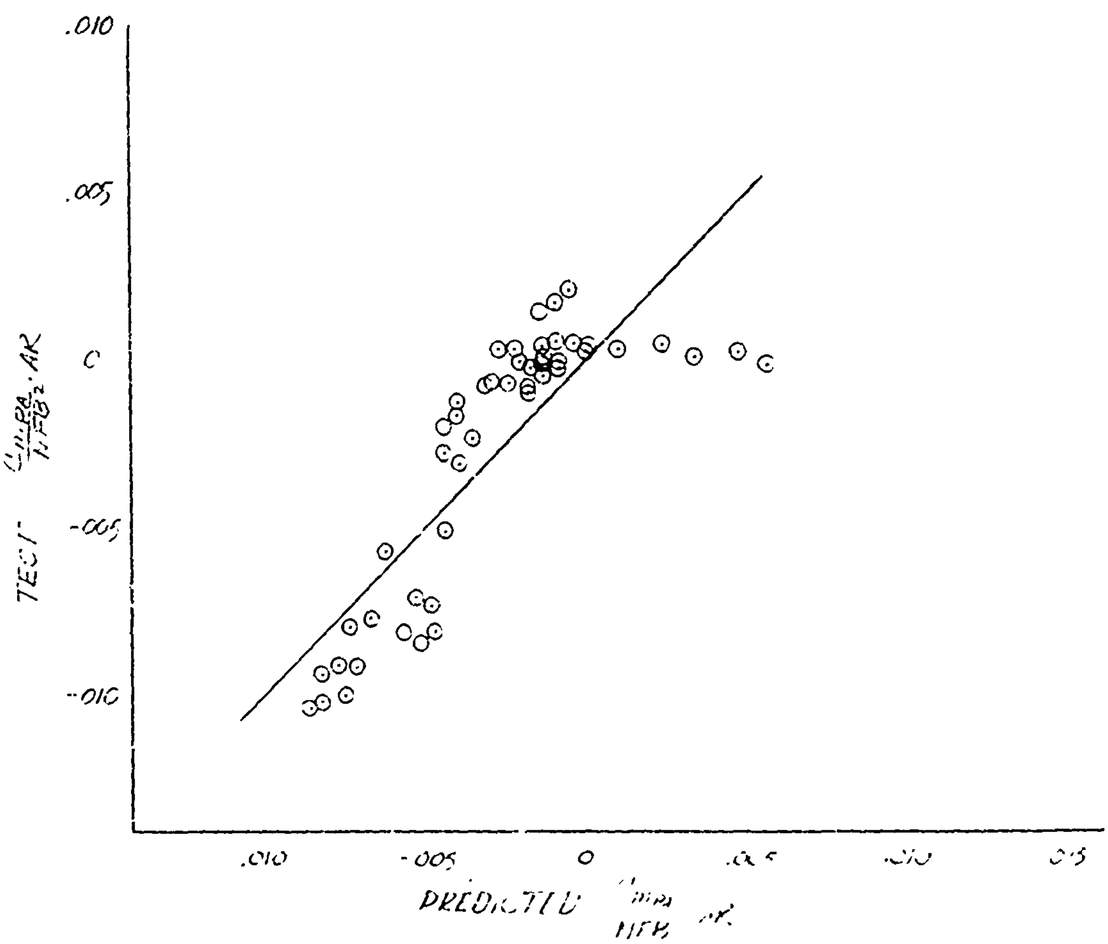
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
PITCHING MOMENT COEFFICIENT

$\alpha_{LOAD} = 16^{\circ}, \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{m_{PA}}}{NFB^2} AR = .0581977 - .0003116\ell - .0004020D + .0000269C + .0000098\Delta X - .0000046 \frac{PA}{FA} \times FSPD + .0017064M^2$$



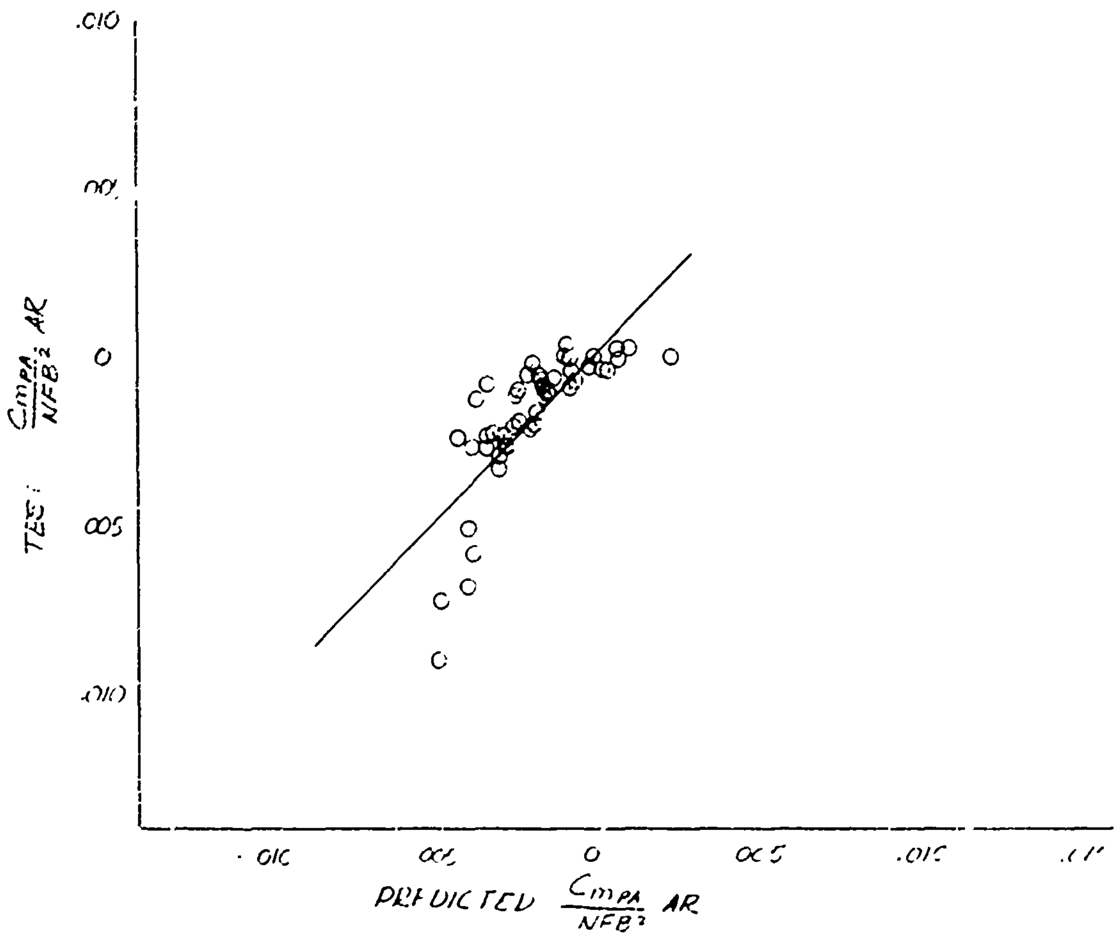
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
PITCHING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{m_{PA}}}{NFB^2} AR = .0148426 - .0000807\ell - .0001362D + .0000206C + .0000135\Delta X - .0000013 \frac{PA}{FA} \times FSPD - .0035323M^2$$



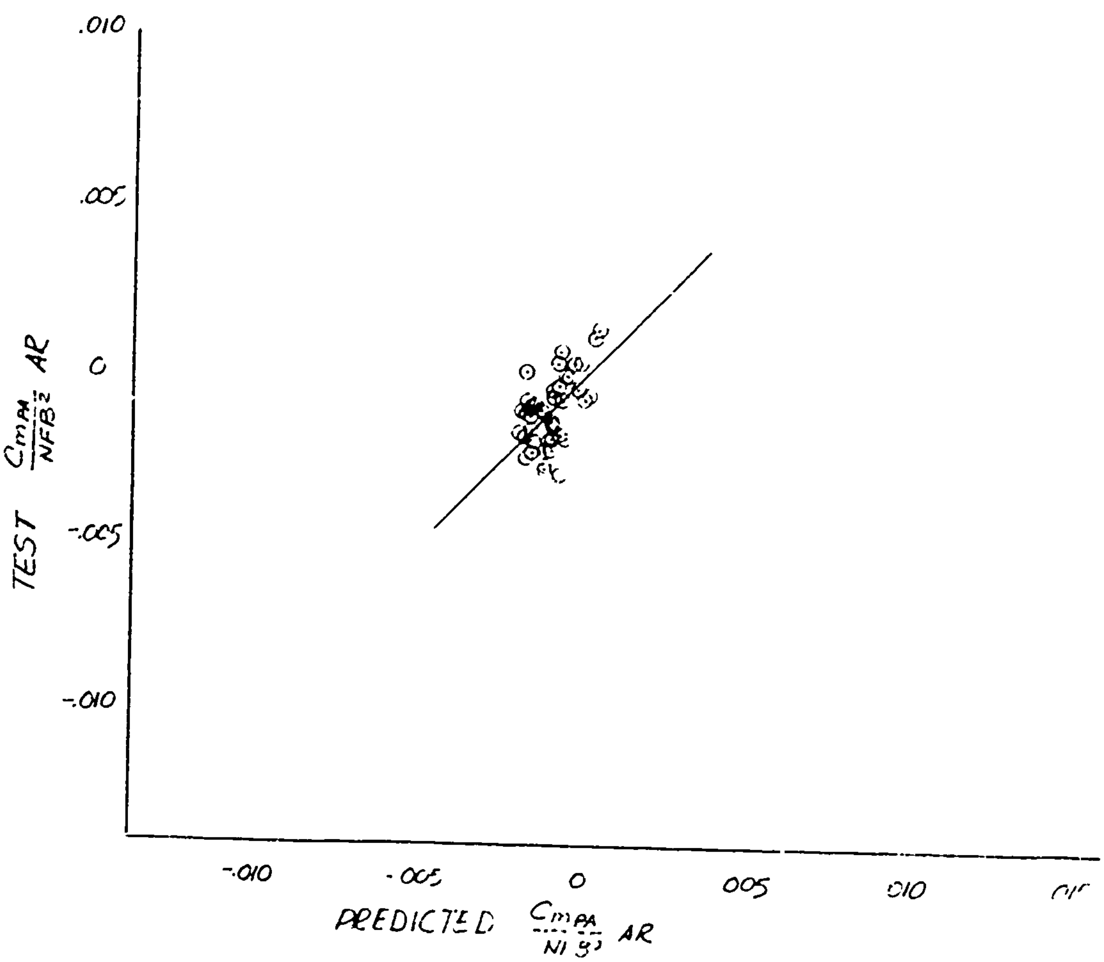
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
PITCHING MOMENT COEFFICIENT

$\alpha_{LOAD} = -4^\circ,\ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{m_{PA}}}{NFB^2} AR = -.0225953 + .0000690\Lambda + .0001233D + .0000284C + .0000432\Delta X + .0000020\,\frac{PA}{FA} \times FSPD - .0005099M^2$$



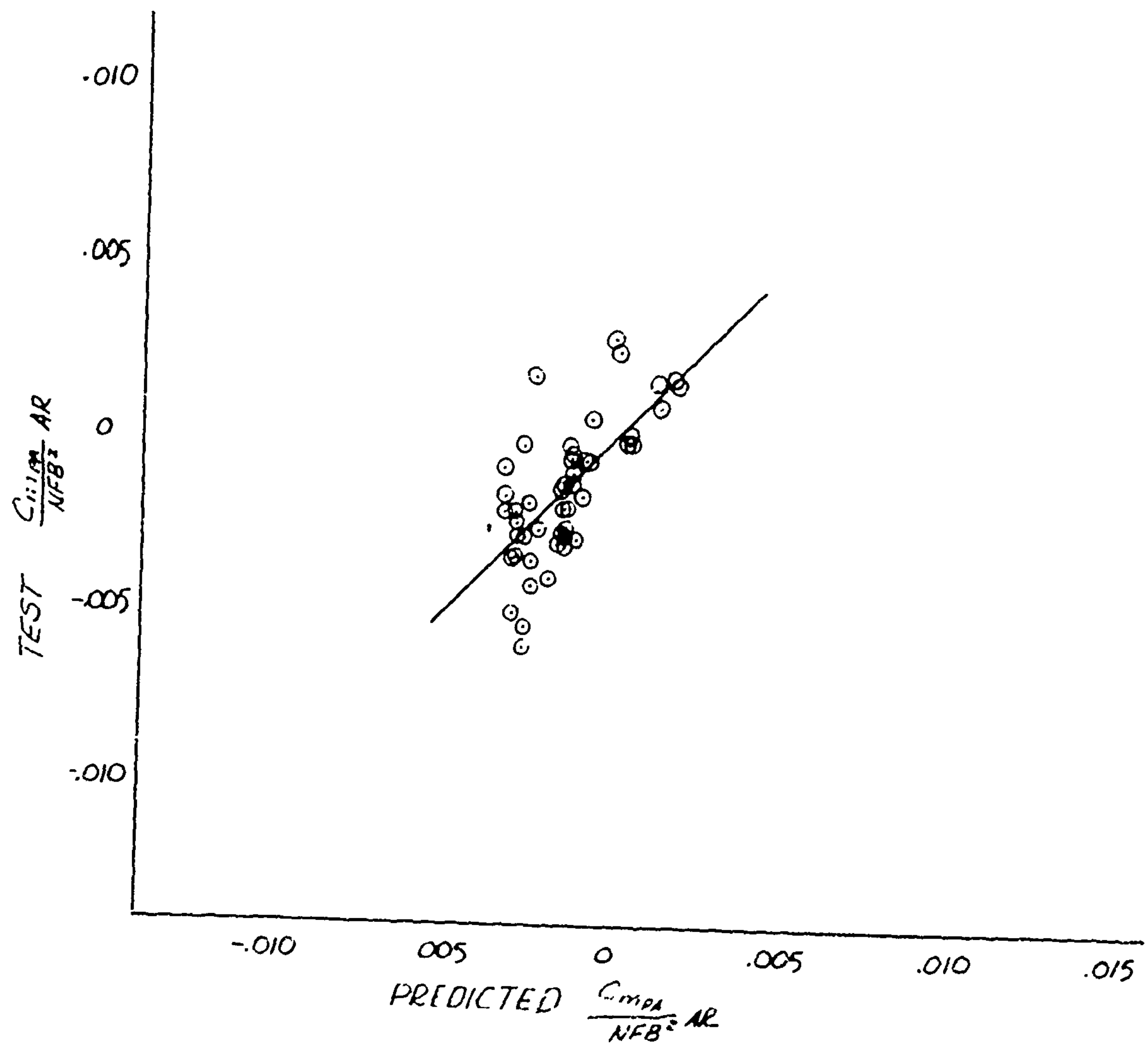
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
PITCHING MOMENT COEFFICIENT

$\alpha_{LOAD} = -9^{\circ}, \ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

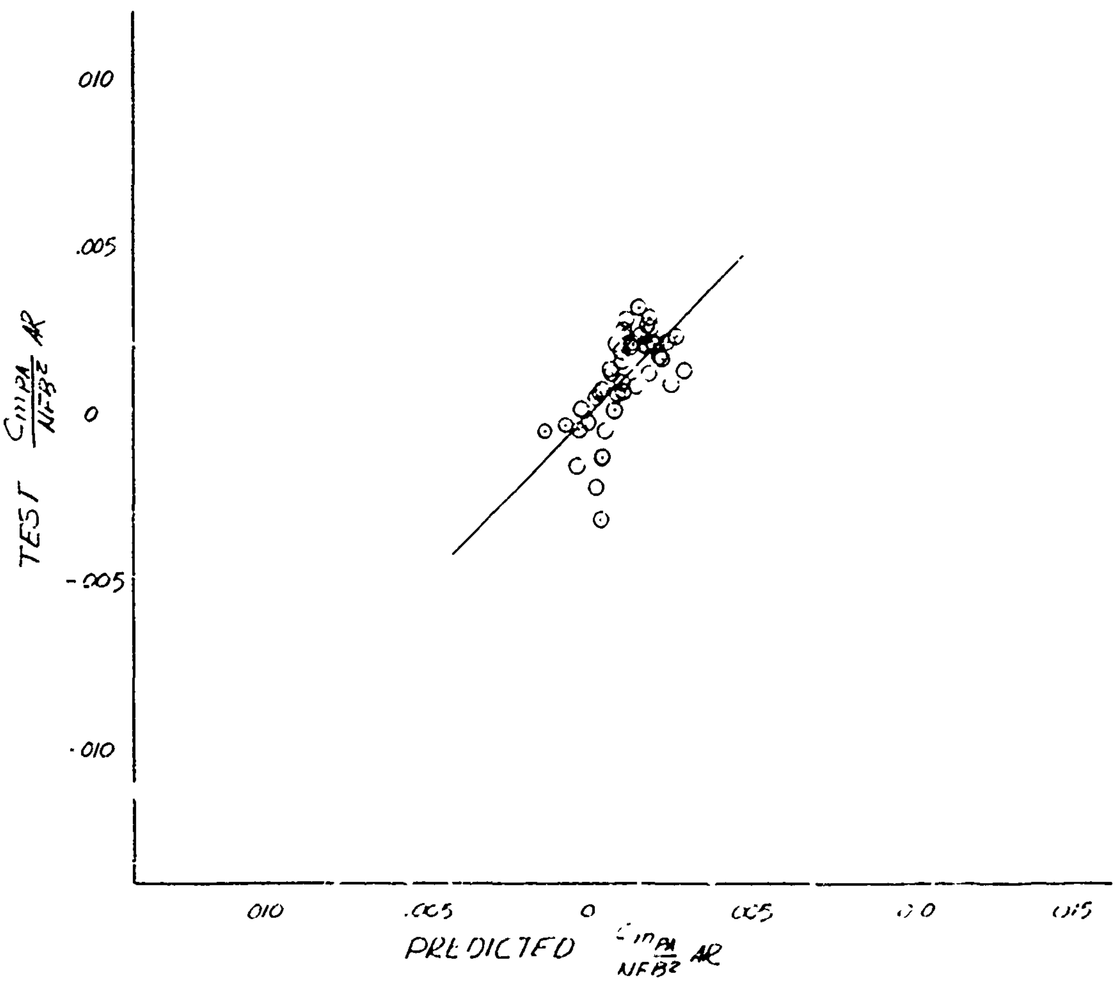
$$\frac{C_{m_{PA}}}{NFB^2} AR = -.0115292 - .0000152\ell + .0000772D + .0000496C + .0000820\Delta X + .0000004 \frac{PA}{FA} \times FSPD + .0009296M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
PITCHING MOMENT COEFFICIENT

$$\alpha_{LOAD} = 6^\circ,\ \beta = +10^\circ$$
$$M = .60 - .95$$
$$\Lambda_{LE} = 16^\circ - 72.5^\circ$$

$$\frac{C_{m_{PA}}}{NFB^2} AR = -.0868547 + .0008703\ell - .0026168D - .0000303C$$
$$-.0000831\Delta X + .0000013 \frac{PA}{FA} \times FSPD - .0025611M^2$$



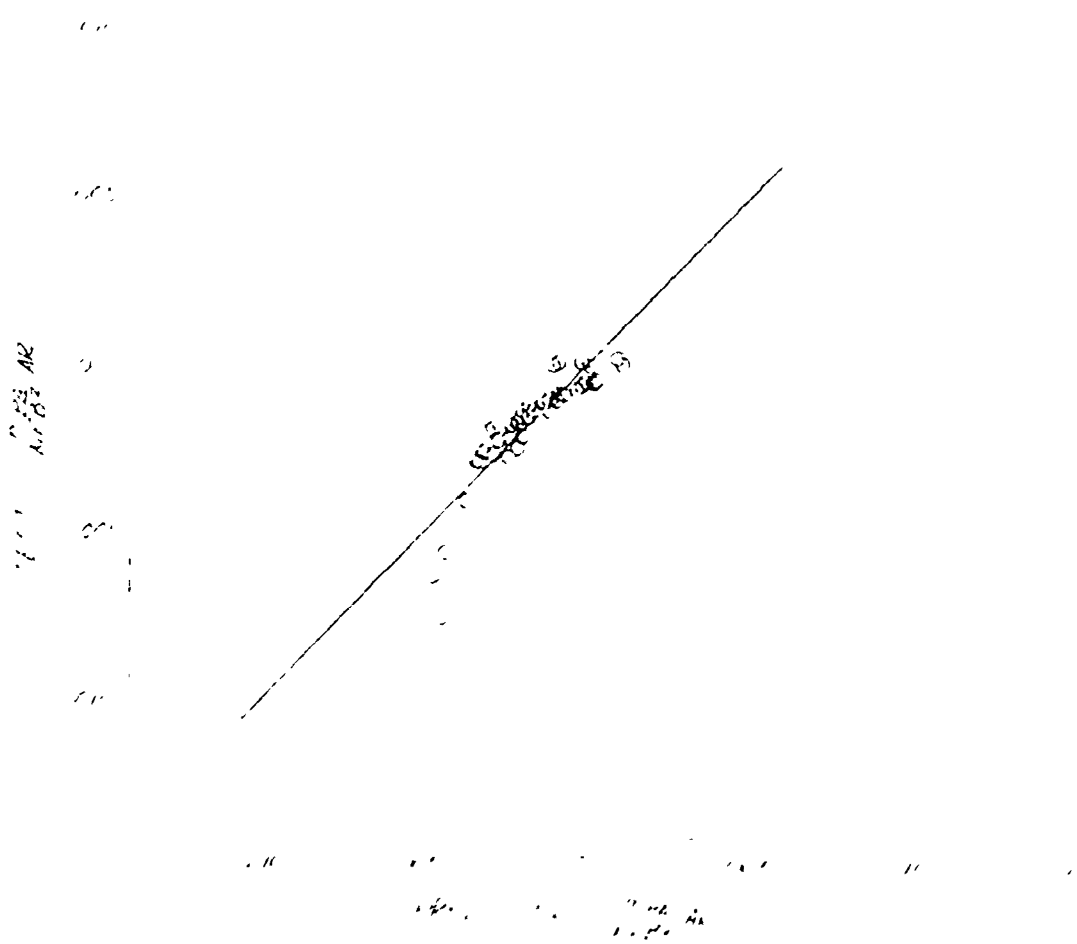
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
PITCHING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \beta = -10^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

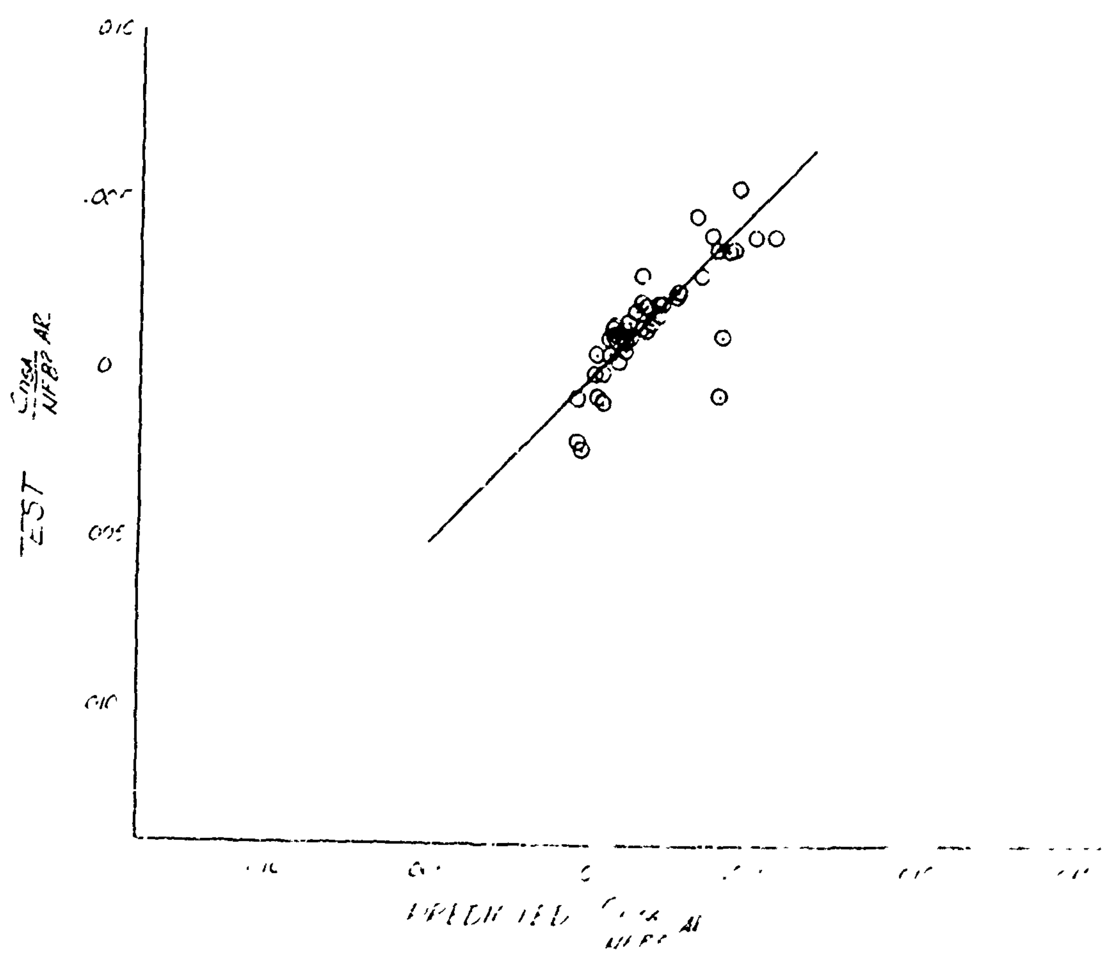
$$\frac{PA}{WEB}, M = -.1707368 + .0007449 \ell - .0026622D - .0000055C - .0000586 \lambda X + .0000016 \frac{PA}{FA} \times FSPD - .0036718M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
YAWING MOMENT COEFFICIENT

$$\alpha_{LOAD} = 16^\circ,\ \beta = 0^\circ$$
$$M = .60 - .95$$
$$\Lambda_{LE} = 16^\circ - 72.5^\circ$$

$$\frac{C_{n_{SA}}}{NFB^2} AR = .0460505 - .0005154\ell + .0016293D + .0000608C + .0001262\Delta X - .0000025\frac{SA}{FA} \times FSPD - .0019533M^2$$



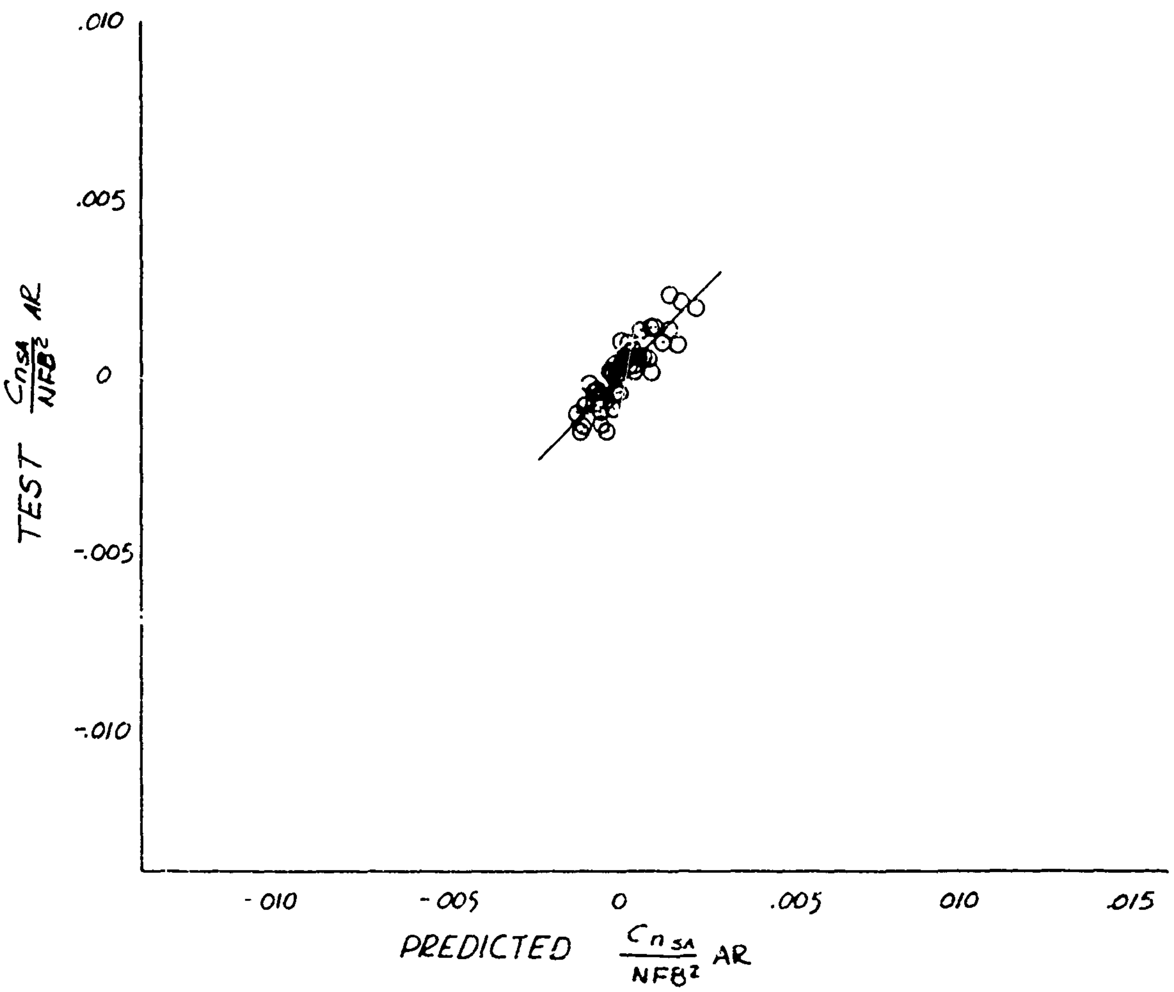
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^\circ,\ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{n_{SA}}}{NFB^2} AR = .0326935 - .0004437\ell + .0016805D + .00004537C + .0001006\ell X - .0000008 \frac{FA}{SA} \times FSPD - .0014820M^2$$



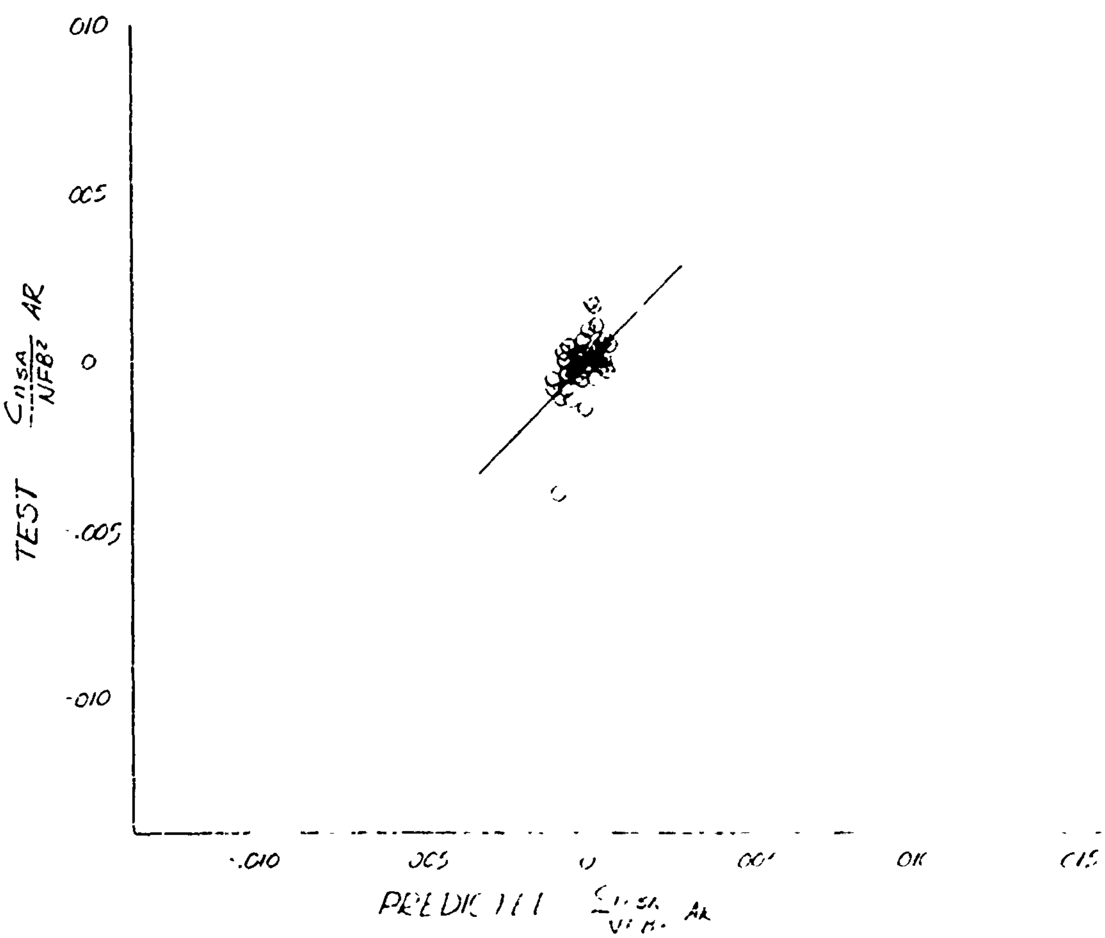
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = -4^{\circ}$, $\beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{n_{SA}}}{NFB^2} AR = .0281080 - .0003168\ell + .0011596D + .0000131C$$
$$+ .0000471\Delta X - .0000011 \frac{SA}{FA} \times FSPD - .0010032M^2$$



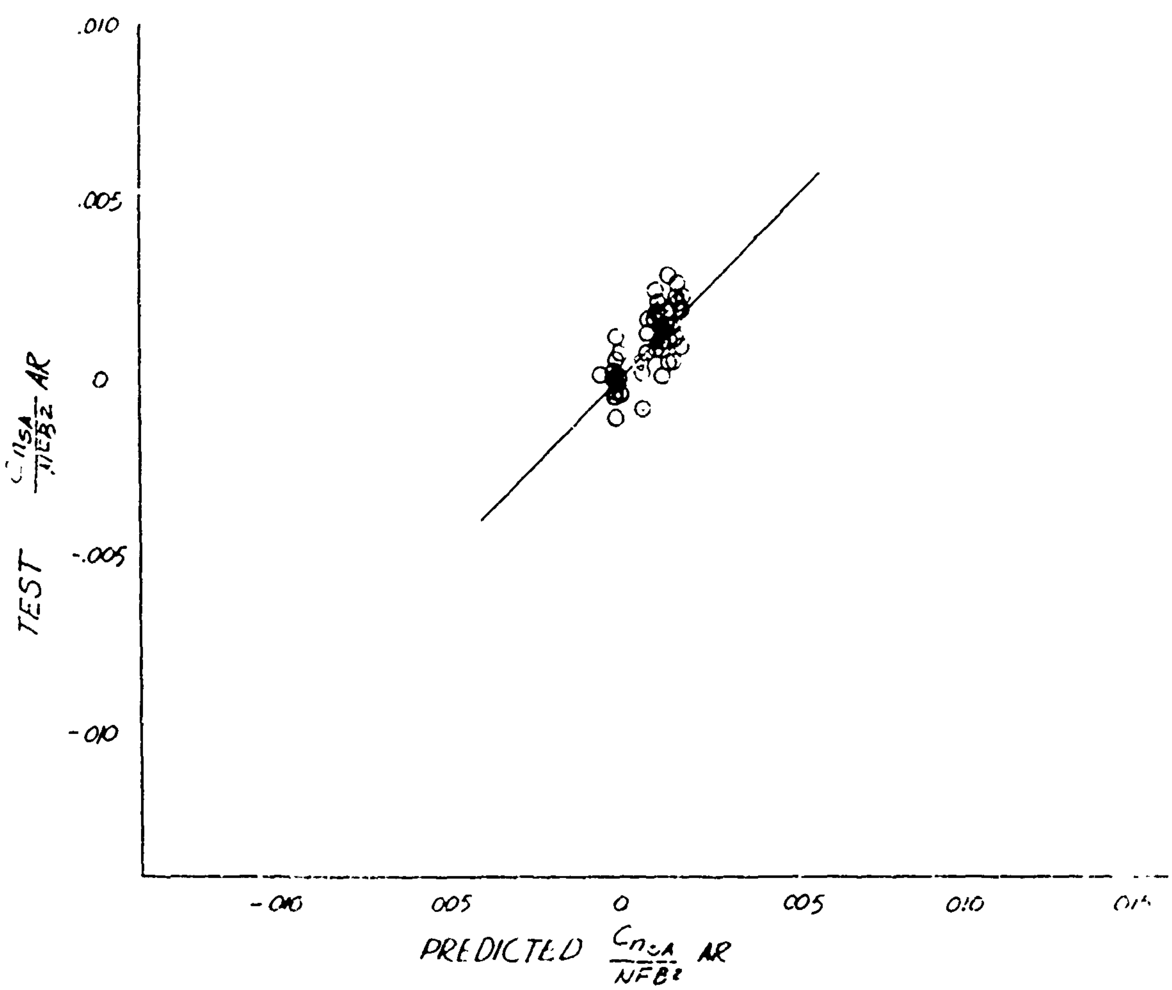
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = -9^\circ,\ \beta = 0^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{n_{SA}}}{NFB^2} AR = .0045833 - .0001016\ell + .0005686D + .0000075C + .0000443\Delta X - .0000014 \frac{SA}{FA} \times FSPD + .0000545M^2$$



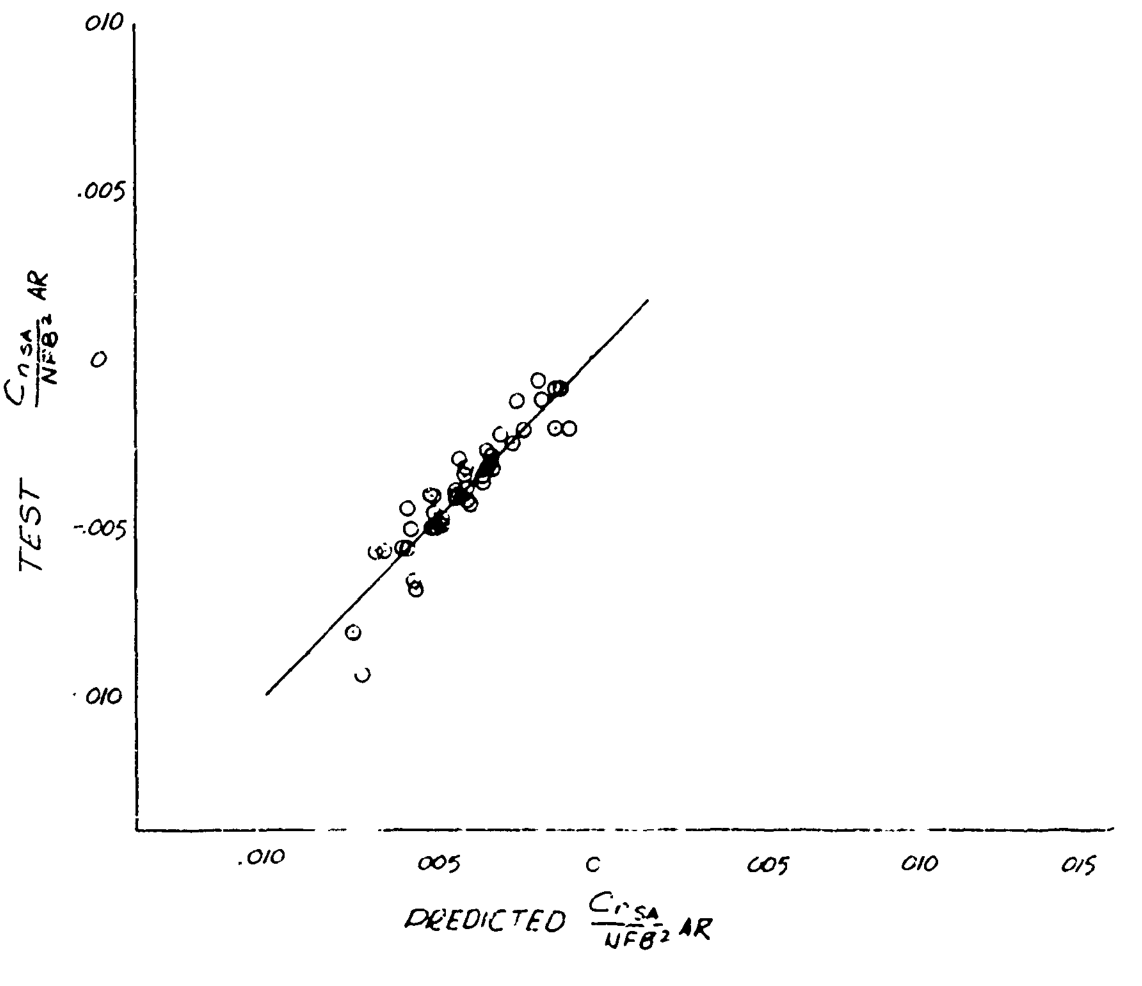
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^\circ,\ \beta = -10^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{Cn_{SA}}{NFB^2} AR = -.0149745 + .0002443\ell - .0013014D + .0000030C - .0000270\Delta X - .0000022\frac{SA}{FA} \times FSPD - .0028448M^2$$



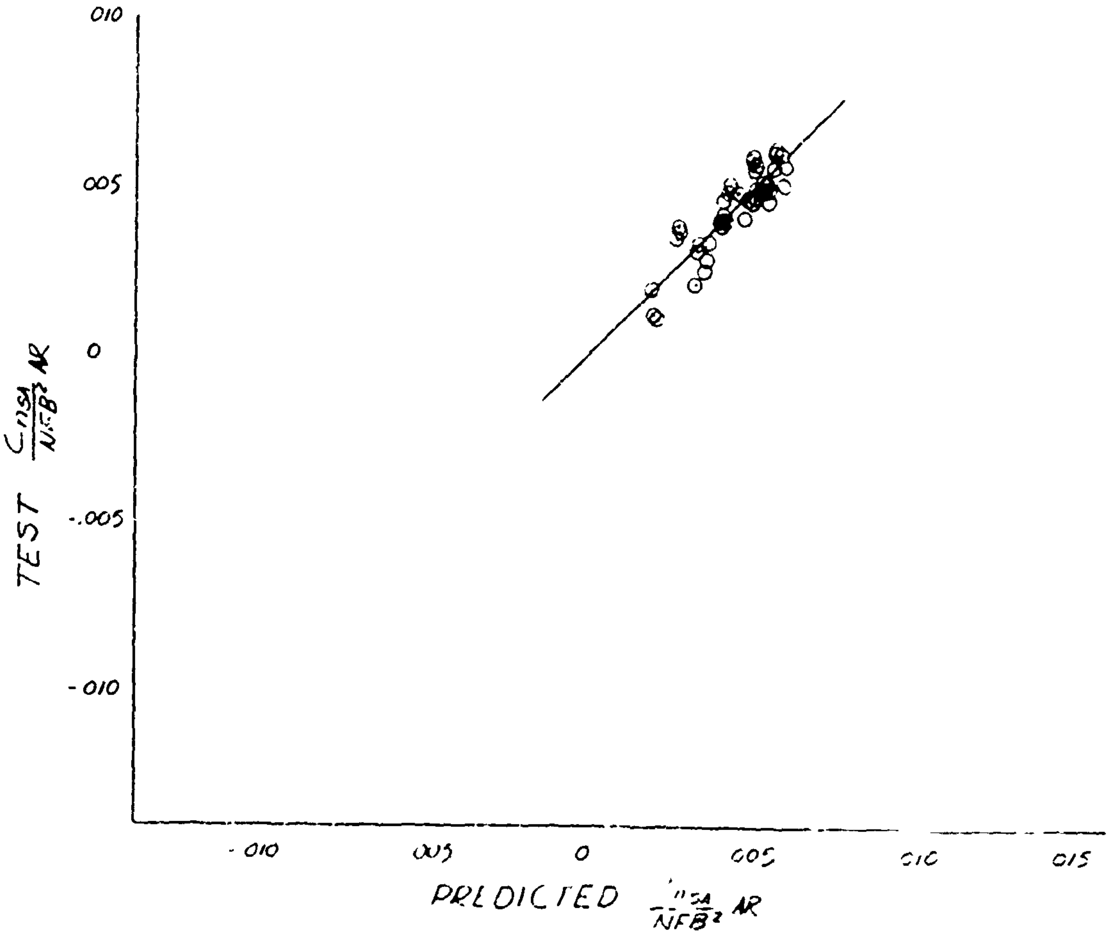
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
YAWING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \beta = +10^{\circ}$

$M \approx .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

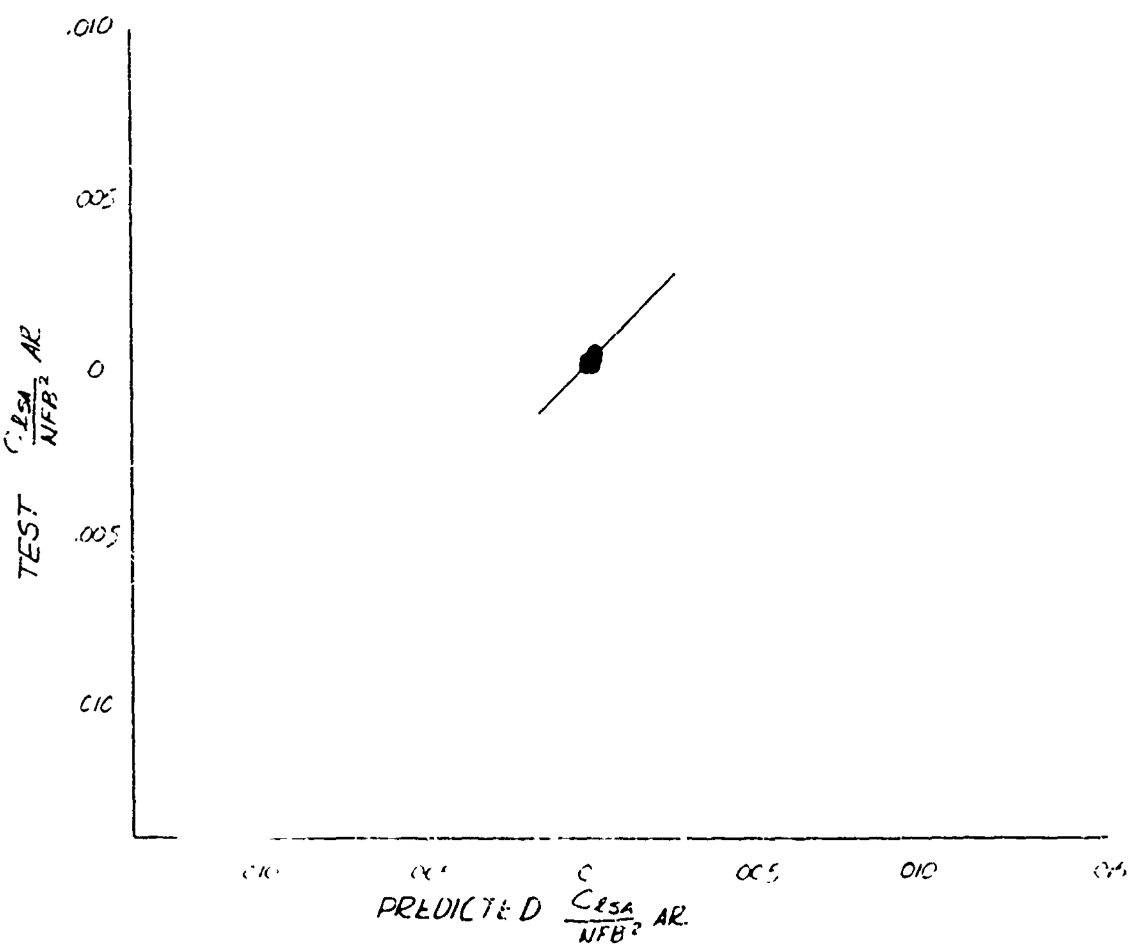
$$\frac{C_{n_{SA}}}{NFB^2} AR = .0613923 - .0007966\,\ell + .0031906D + .0000579C + .0001628\,\ell X - .0000007\,\frac{SA}{FA} \times FSPD - .0001654M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
ROLLING MOMENT COEFFICIENT

$$\alpha_{LOAD} = 16^\circ,\ \beta = 0^\circ$$
$$M = .60 - .95$$
$$\Lambda_{LE} = 16^\circ - 72.5^\circ$$

$$\frac{C_{\ell SA}}{NFB^2} AR = .0048296 - .0000321\alpha + .0000705D - .0000026C$$
$$-.0000061X + .00000001 \frac{SA}{FA} \times FSPD + .0000897M^2$$



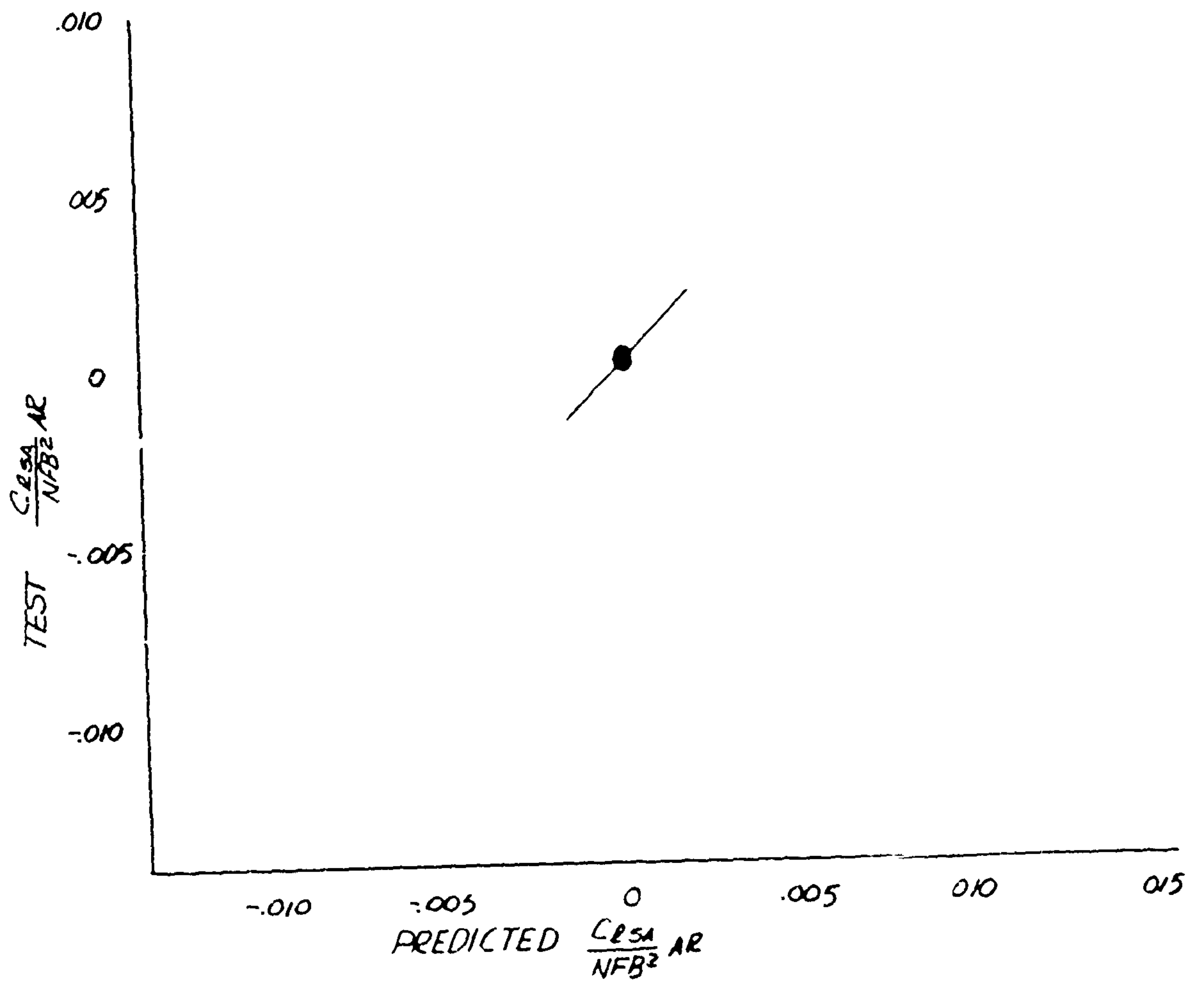
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
ROLLING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

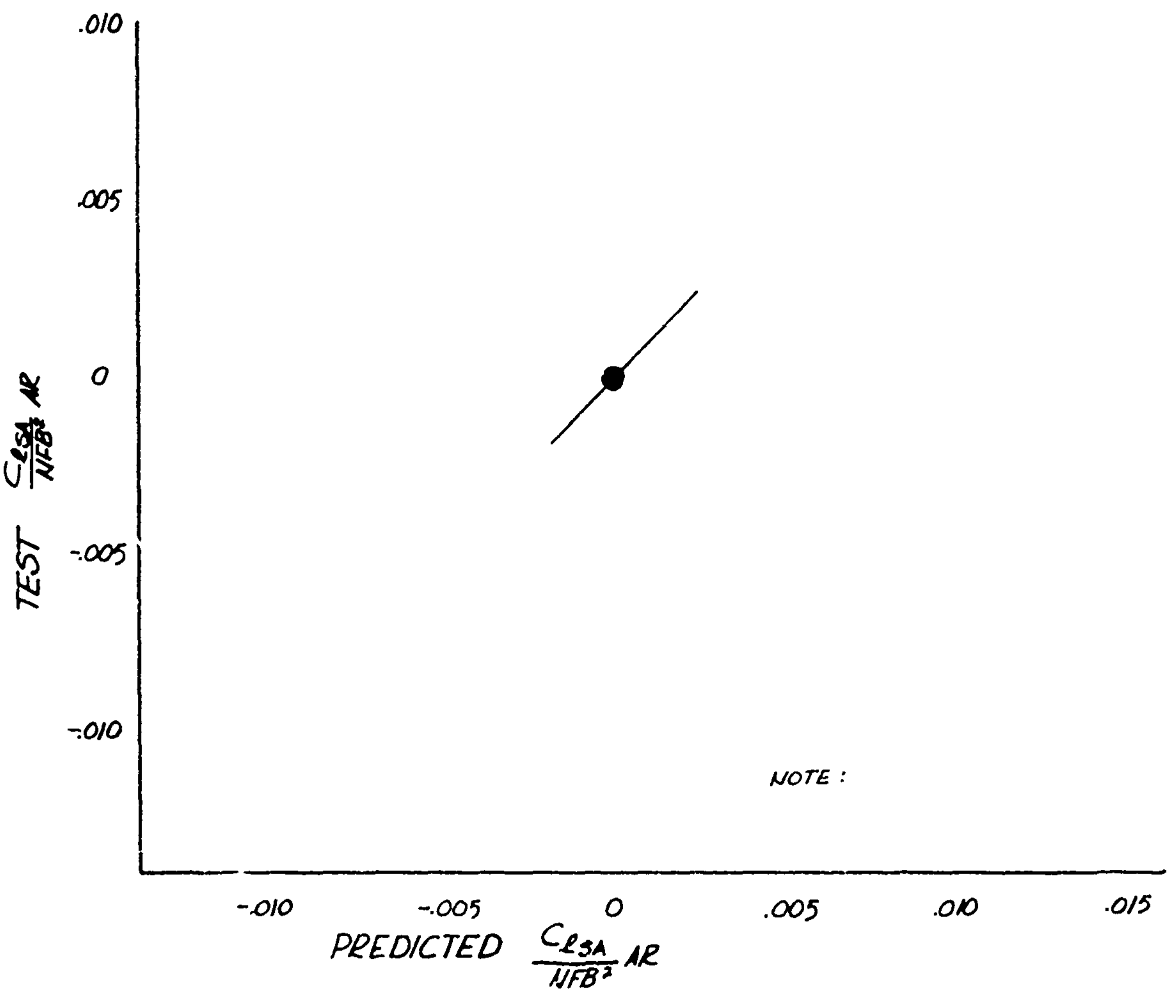
$$\frac{C_{\ell SA}}{NFB^2} AR = -.0007975 + .0000073\ell - .0000212D + .0000002C - .0000002\Delta X + .0000001 \frac{SA}{FA} \times FSPD + .0000626M^2$$



COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
ROLLING MOMENT COEFFICIENT

$$\alpha_{LOAD} = -4^\circ, \ \beta = 0^\circ$$
$$M = .60 - .95$$
$$\Lambda_{LE} = 16^\circ - 72.5^\circ$$

$$\frac{C_{\ell_{SA}}}{NFB^2} AR = -.0056988 + .0000511\ell - .0001508D - .0000009C$$
$$-.0000020\Delta X + .0000001 \frac{SA}{FA} \times FSPD + .0000302M^2$$



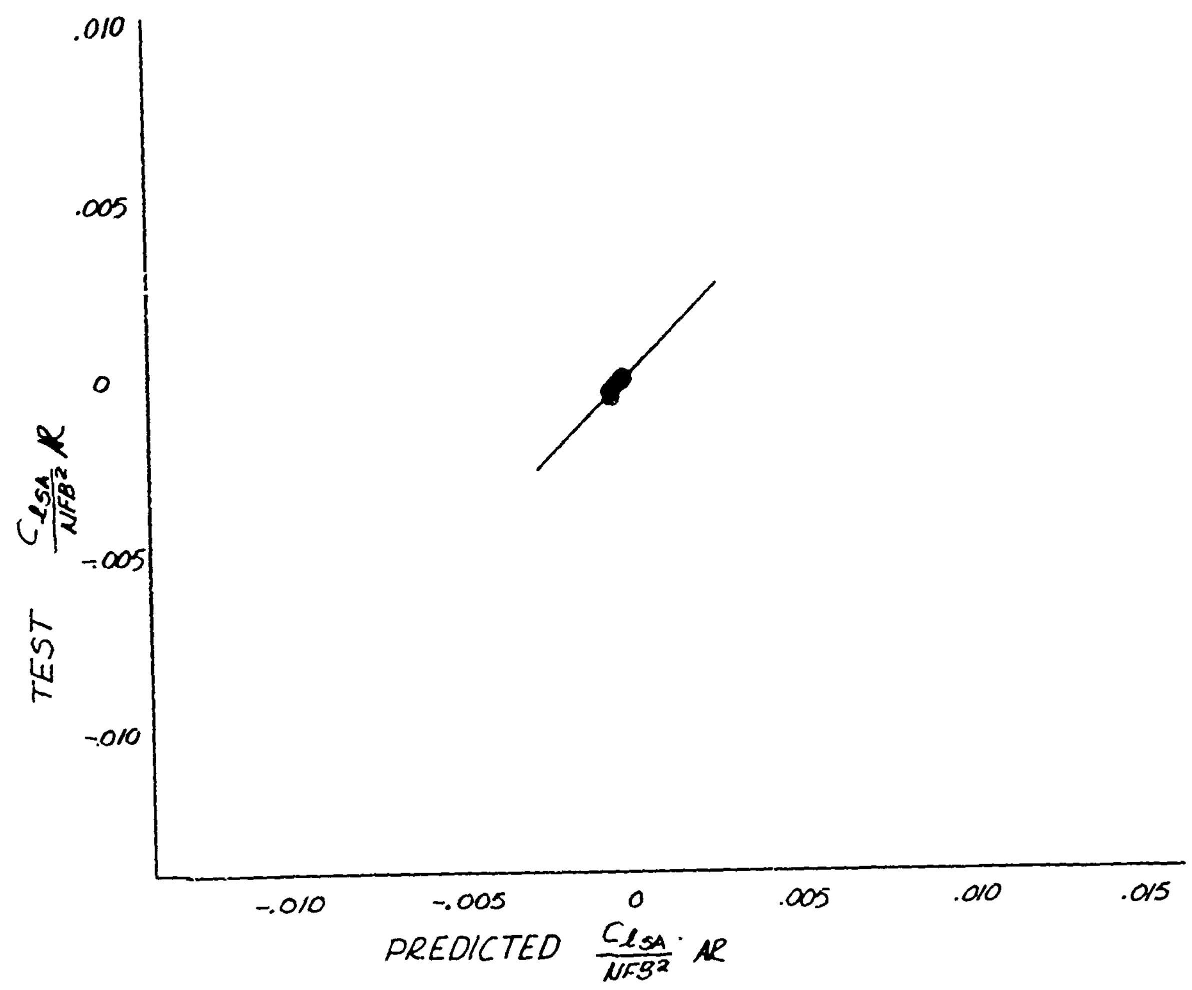
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
ROLLING MOMENT COEFFICIENT

$\alpha_{LOAD} = -9^{\circ}, \ \beta = 0^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{\ell SA}}{NFB^2} AR = -.0066227 + .0000640\,\ell - .0001936D - .0000031C$$
$$-.0000039\Delta X - .00000001 \frac{SA}{FA} \times FSPD - .0000809M^2$$



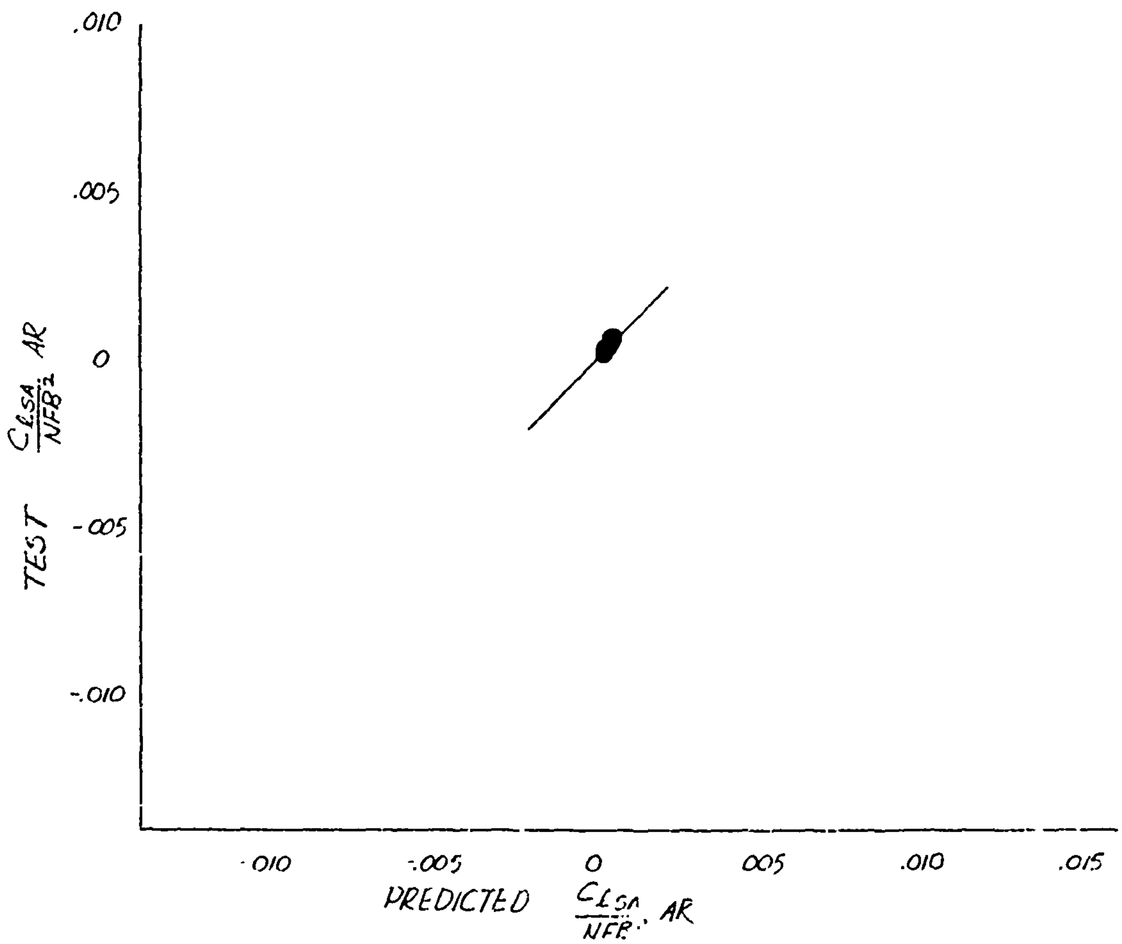
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
ROLLING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^{\circ}, \beta = +10^{\circ}$

$M = .60 - .95$

$\Lambda_{LE} = 16^{\circ} - 72.5^{\circ}$

$$\frac{C_{\ell_{SA}}}{NFB^2} AR = .0023775 - .0000078\lambda - .0000078D - .0000029C - .0000070?X + .00000019 \frac{SA}{FA} \times FSPD + .0001679M^2$$



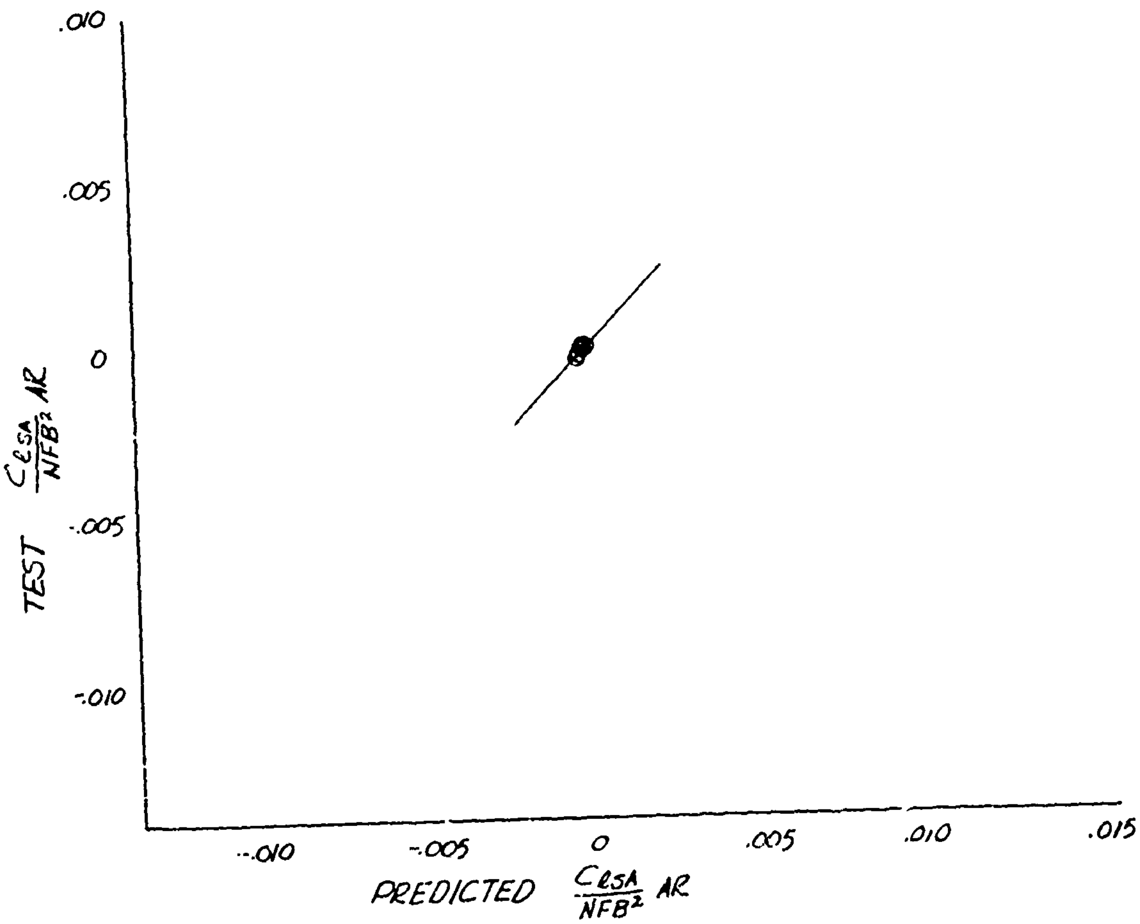
COMPARISON OF TEST AND PREDICTED DATA
FOR SINGLE WEAPON + RACK
Outboard
ROLLING MOMENT COEFFICIENT

$\alpha_{LOAD} = 6^\circ,\ \beta = -10^\circ$

$M = .60 - .95$

$\Lambda_{LE} = 16^\circ - 72.5^\circ$

$$\frac{C_{\ell_{SA}}}{NFB^2} AR = -.0057540 + .0000544\ell - .0001822D + .0000005C - .0000019\Lambda X + .00000005\frac{SA}{FA} \times FSPD - .0001478M^2$$



APPENDIX II

This appendix contains the mathematical relationships and equation coefficients to determine the five components of aerodynamic forces or moments acting on various external store arrangements.

This appendix is self-contained so that it may be removed and used more conveniently.

The mathematical relationships provided are intended for use in preliminary design.

AFFDL-TR-73-126
Appendix II

DEVELOPMENT OF PREDICTION TECHNIQUES FOR AERODYNAMIC LOADS ACTING ON EXTERNAL STORES

APPENDIX II - Handbook for Determination of Aerodynamic Loads Acting on External Stores

M. B. Sullivan

GNERAL DYNAMICS, CONVAIR AEROSPACE DIVISION

TECHNICAL REPORT AFFDL-TR-73-126, Appendix II

27 December 1974

Approved for public release; distribution unlimited.

AIR FORCE FLIGHT DYNAMICS LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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LIST OF TABLES

SECTION IA

INTRODUCTION

This appendix presents calculation techniques for the determination of aerodynamic forces and moments acting on various aircraft external store configurations. The methods are presented in an aerodynamic handbook format and the results are intended for use in the determination of critical design loads during the preliminary design phase of aircraft development. The methods presented are in an equation format so that the aerodynamic normal load, side load, pitching moment, yawing moment, and rolling moment may be calculated for a specific external store configuration in proximity with other stores. The techniques presented allow the determination of store loads as a function of geometry parameters associated with the wing planform, the store geometry, the relationship of the stores to the wing, and the proximity of the fuselage and other adjacent stores. Each component of the aerodynamic store load may be calculated at particular angles of attack of the store and at a particular sideslip angle Calculations may be made at Mach numbers from 0.6 to 0.95 for generalized store configurations and for a limited set of configurations up to Mach numbers of 1.6.

SECTION 2A

APPLICATION OF PREDICTION TECHNIQUES

All of the methods described in this appendix for evaluating the aerodynamic forces and moments acting on various external store configurations were developed from the empirical correlations of F-111 experimental data. These correlations were accomplished using statistical regression analysis techniques. The statistical regression techniques utilized produced linear mathematical relationships between the particular aerodynamic force or moment being investigated and various geometric correlating parameters. The investigations were conducted for various major classifications of stores and these classifications are illustrated in Figure 1A.

To apply the methods of this handbook to a particular external store configuration reference is first made to the schematic diagrams shown in Figure 1A to establish that the weapon-rack-pylon configuration is a weapon cluster or a single weapon. If the configuration is a weapon cluster aerodynamic loads may be calculated on the outermost pylon location from one set of relationships. If the weapon cluster is mounted on any of the inboard pylon locations another set of relationships is utilized for all these locations. For a weapons cluster two or three weapons on a triple ejector rack (TER) or four or six weapons on a multiple ejector rack (MER or BRU) may be analyzed.

For single weapons on a particular pylon location successful correlations were accomplished and relationships developed for the outer weapon location only. As explained in Section 4 of the report, correlations were not successful for the single weapons on the inboard pylon locations and predictions for these locations would depend on determination of component force and moment data for specific store arrangements from Table III of the report or from other data sources such as NASA data (References).

The data used in the correlation studies was obtained from wind tunnel testing of the F-111 1/12th scale model with various external store arrangements. A general arrangement of the F-111 is shown in Figure 2A. The wing planform with pylon locations noted as a function of sweep angle is shown in Figure 3A.

Until some experience is accumulated in applying the methods of this handbook to other configurations it is recommended that the geometric limitations of Table IA not be exceeded. These limitations are a summary of the maximum and minimum wing sweep angles and the diameter and

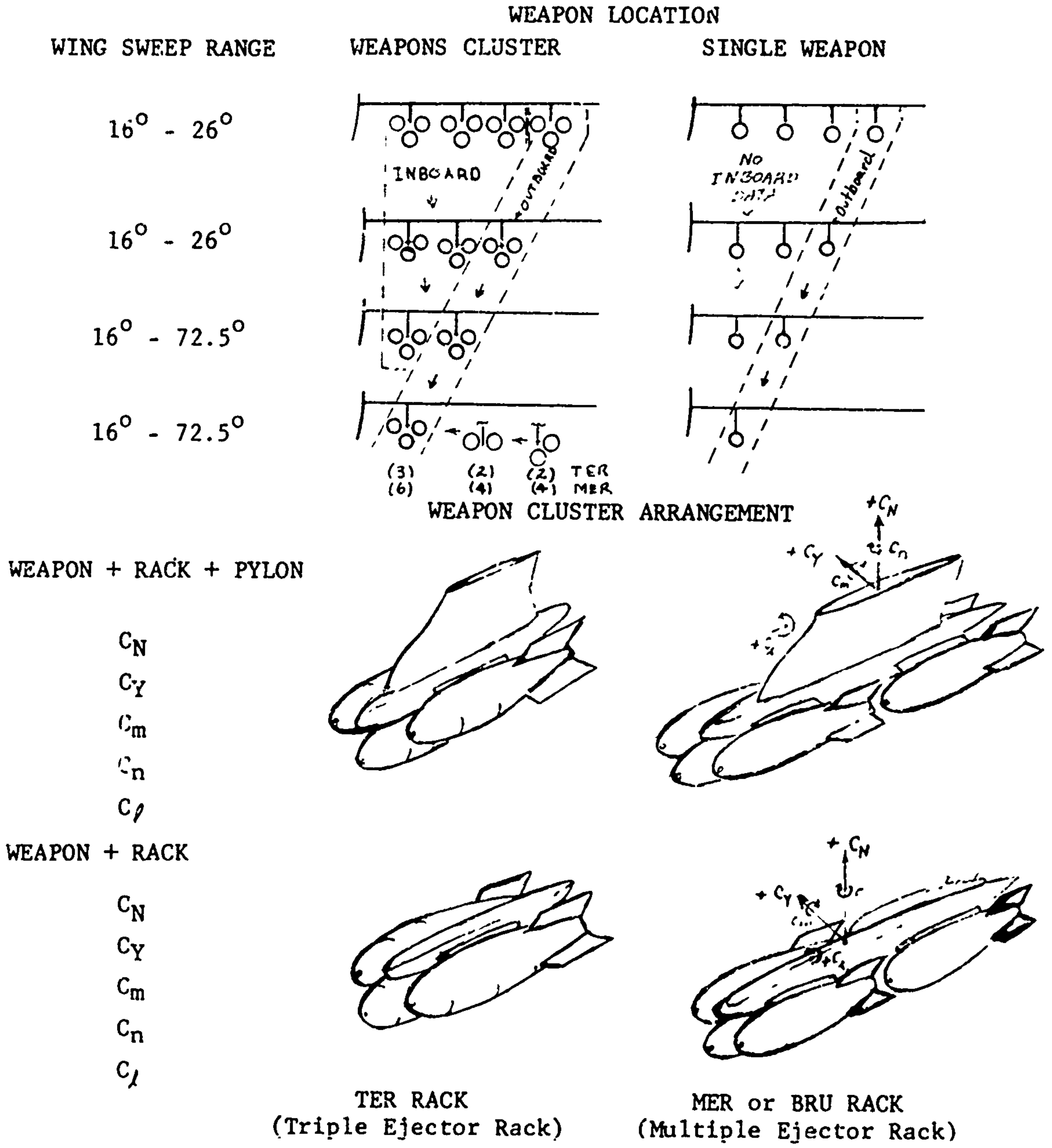
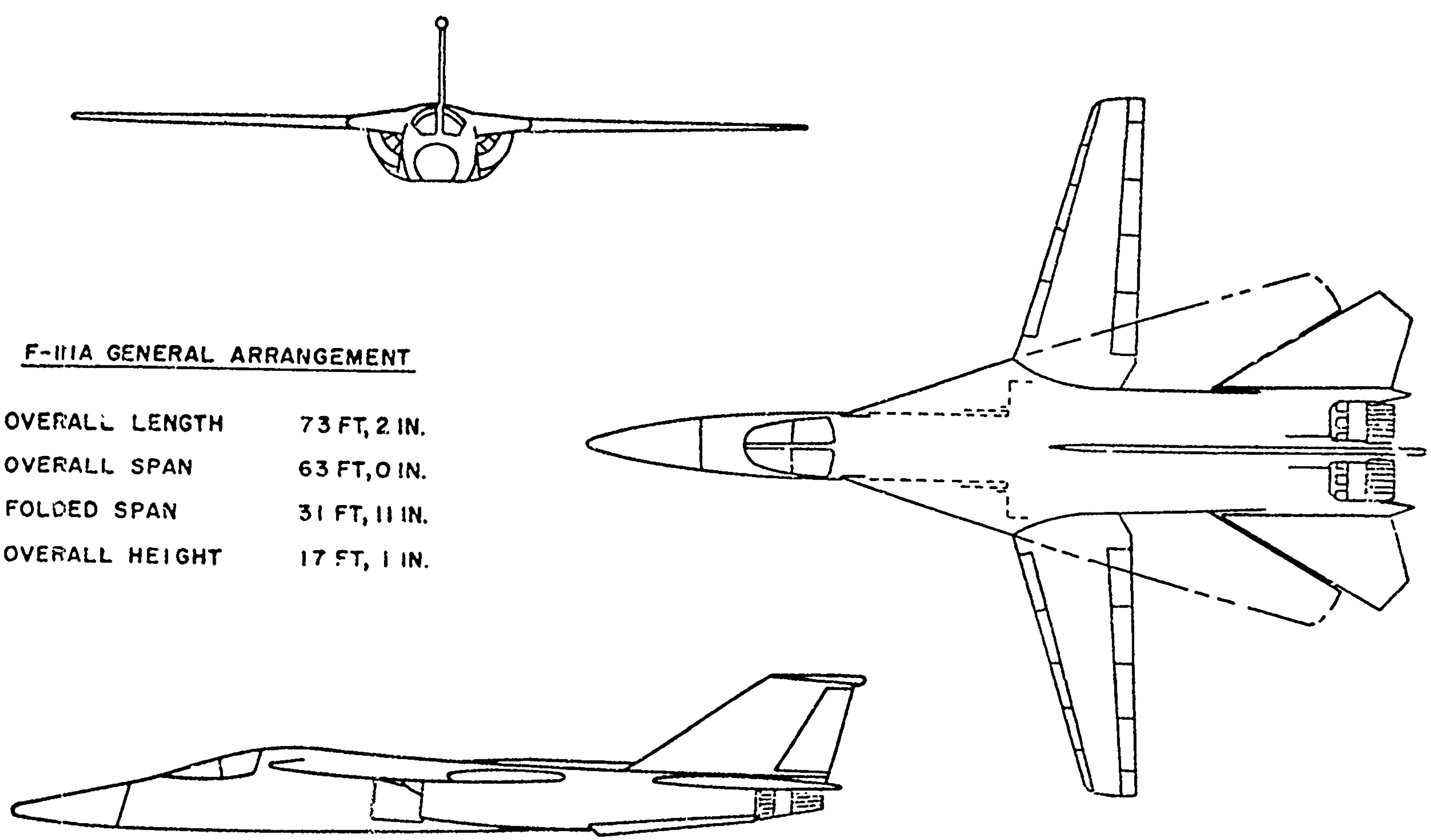
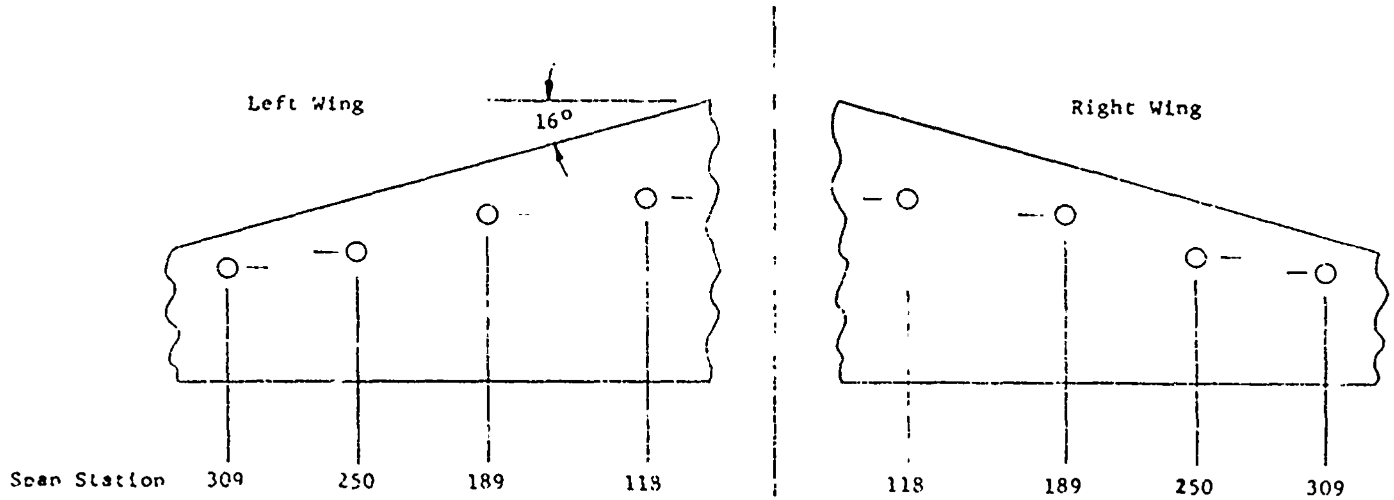


Figure 1A Weapon Configuration Coverage



Figre 2A General Arrangement of F-111



Λ = 16°				Λ = 26°				Λ = 35°				Λ = 50°				Λ = 72.5°			
Span = [illegible]55.910				Span = 719.944				Span = 676.585				Span = 579.072				Span = 383.8			
Span Sta	% Span	Chord	% Chord	Span Sta	% Span	Chord	% Chord	Span Sta.	% Span	Chord	% Chord	Span Sta.	% Span	Chord	% Chord	Span Sta.	% Span	Chord	% Chord
115	.312	119.04	.3040	115	.319	123.10	.3147	110	.325	130.64	.3255	101	.349	155.29	.3491	84	.438	270.04	.4297
183	.50	99.90	.2374	183	.508	102.96	.2464	175	.517	108.90	2557	156	.539	128.47	.2764	116	.604	217.67	.3492
250	.66	83.34	.3057	240	.667	86.20	.3152	227	.671	91.48	.3269	196	.677	108.75	.3507	134	.698	189.21	.4313
309	.818	67.46	.2365	297	.825	69.53	.2454	280	.828	73.54	.2547	240	.829	86.74	.2754	160	.834	14[illegible].90	.3481

Figure 3A Planform View of F-111 Pylon Stations

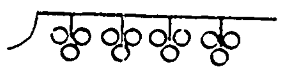
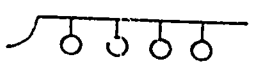
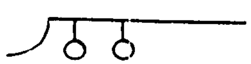
Weapon Cluster	Λ_{LE}	Maximum Weapon Limitations Diameter	Maximum Weapon Limitations Length	Rack Configuration (No. Bombs)
 1 to 4 stations	16° - 30°	18″	180″	MER - (2 or 3) TER - (4 or 6)
 1 or 2 stations	16° - 72.5°	18″	180″	MER - (3)(2 or 3) TER - (6)(4 or 6)
Single Weapon				
 1 to 4 stations	16° - 30°	24″	180″	Rack Exposed or Faired (1)
 1 or 2 stations	16° - 72.5°	24″	180″	Rack Exposed or Faired (1)

Table IA Geometry Limitations Applicable to Correlation Studies

length of the various weapons included in the empirical correlations.

In the format presented in Section 3A, linear equations are presented which allow calculation of five components of force or moment acting on various external store arrangements. The coefficients for these equations are contained in tabular form and are grouped according to major store configurations. The calculations are made for specific angles-of-attack for +16 degrees to -9 degrees and for +10 and -10 degrees sideslip at an angle of attack of +6 degrees.

SECTION 3A

CALCULATION OF EXTERNAL STORE AERODYNAMIC LOADS

The methods used in this appendix to determine the aerodynamic loads acting on an external store configuration were derived from statistical techniques which produced a linear equation. This equation contains various geometric correlating parameters (Table IIA) and allows the calculation of a particular force or moment coefficient acting on an external store configuration at specific angles of attack. The aerodynamic coefficients are calculated as follows:

<u>Normal Load Coefficient</u>

$$C_{N_{PA}} \cdot \frac{AR}{NFB^2}\,\frac{NB^2}{NFB^2} = C_1\,\frac{PA}{FA}(FSPD) + C_2\,\ell + C_3 d + C_4 C + C_5\,\Delta x + C_6 M^2 + C_7 + C_{MER}$$

$$C_{N_{PA}} = \frac{\text{Normal Load}}{q\ (\text{Planform Area})}$$

<u>Side Force Coefficient</u>

$$C_{y_{SA}} \cdot \frac{AR'}{NFB^2}\,\frac{NB^2}{NFB^2} = C_1\,\frac{SA}{FA}(FSPD) + C_2\,\ell + C_3 d + C_4 C + C_5\,\Delta x + C_6 M^2 + C_7 + C_{MER}$$

$$C_{y_{SA}} = \frac{\text{Side Load}}{q\ (\text{Side Projected Area})}$$

Pitching Moment Coefficient

$$C_{m_{PA}} \cdot \frac{AR}{NFB^2} \frac{NB^2}{NFB^2} = C_1 \frac{PA}{FA}(FSPD) + C_2 \ell + C_3 d + C_4 C + C_5 \Delta x + C_6 M^2 + C_7 + C_{MER}$$

$$C_{m_{PA}} = \frac{\text{Pitching Moment}}{q \text{ (Planform Area)(Overall Length)}}$$

Yawing Moment Coefficient

$$C_{n_{SA}} \cdot \frac{AR'}{NFB^2} \frac{NB^2}{NFB^2} = C_1 \frac{SA}{FA}(FSPD) + C_2 \ell + C_3 d + C_4 C + C_5 \Delta x + C_6 M^2 + C_7 + C_{MER}$$

$$C_{n_{SA}} = \frac{\text{Yawing Moment}}{q \text{ (Side Projected Area)(Overall Length)}}$$

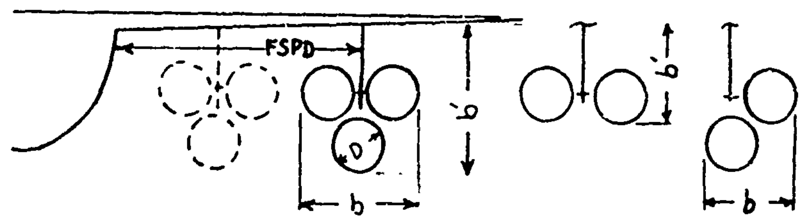
Rolling Moment Coefficient

$$C_{\ell_{SA}} \cdot \frac{AR'}{NFB^2} \frac{NB^2}{NFB^2} = C_1 \frac{SA}{FA}(FSPD) + C_2 \ell + C_3 d + C_4 C + C_5 \Delta x + C_6 M^2 + C_7 + C_{MER}$$

$$C_{\ell_{SA}} = \frac{\text{Rolling Moment}}{q \text{ (Side Projected Area)(Overall Length)}}$$

The coefficients allow the calculation of an aerodynamic force or moment for weapons cluster configurations on any pylon location or for single weapons at outboard pylon locations. The aerodynamic coefficient may be calculated for angles of attack of +16, +6, -4 and -9 degrees at zero

Table II A GEOMETRY DEFINITIONS



SA	= SIDE PROJECTED AREA
FA	= FRONTAL AREA OF WEAPONS + RACK + PYLON
PA	= PLANFORM AREA OF WEAPONS + RACK + PYLON
FSPD	= FUSELAGE SIDE TO ℄ OF PYLON DISTANCE
AR.	= b^2/PA or b'^2/SA
l	= OVERALL LENGTH OF LOAD ON PYLON/RACK
D	= DIAMETER OF WEAPON
C	= WING CHORD AT PYLON LOCATION
ΔX	= WEAPON NOSE TO WING L.E. X-DISTANCE
NFB	= NUMBER OF FRONT BOMBS
NB	= NUMBER OF BOMBS
M	= MACH NUMBER
λ	= WING SWEEP

sideslip angles and +10 and -10 degrees sideslip angles at 6 degrees angle of attack for Mach numbers from 0.6 to 0.95. The equations yield estimates of five components of aerodynamic forces and moments acting on various external store configurations as previously illustrated in Figure 1A. Coefficients for particular external store arrangements are contained in Tables III through VIII as follows:

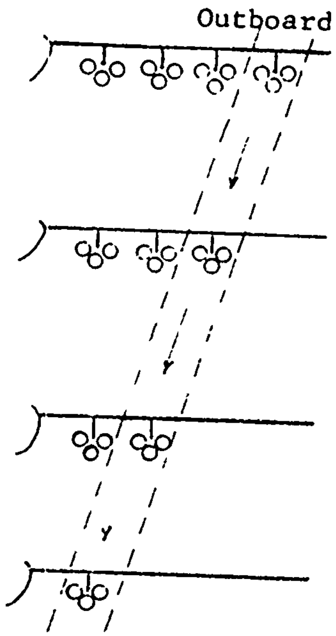
Two sample calculations are shown on page 307 for the normal load acting on two different types of external store configurations.

For a weapon cluster arrangement, two types of racks are considered as shown in Figure IA. Aerodynamic loads acting on a rack containing up to three weapons (TER rack) or on a rack containing up to six weapons (MER rack) may be determined.

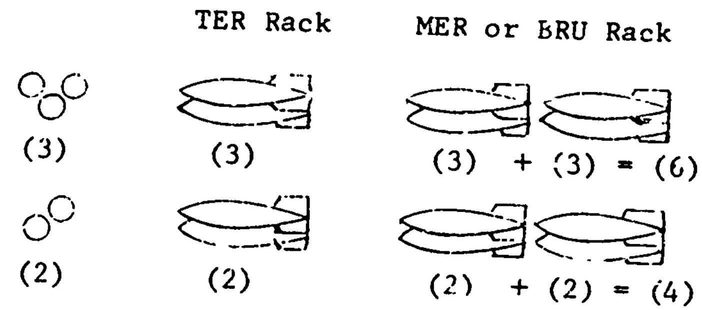
For the TER configurations the term C_{MER} is zero. For MER rack configurations the coefficient C_{MER} is obtained from Tables III A-2 through VI A-2.

The terms outboard and inboard refer to pylon station locations with respect to other pylons. The terms are best defined by referring to Figure IA or the "Weapon Location" depicted in Tables III A-1 through VIII A-1.

WEAPON LOCATION



FLIGHT CONDITION			SEE TABLE III A-2, PAGE 296. PREDICT EXTERNAL FORCE OR MOMENT FROM TABLE SECTION:				
N.M.	α	β	C_N	C_Y	C_m	C_n	C_1
0.5-0.95	$+16^\circ/-9^\circ$	0°	(a) to (d)	(a) to (d)	(a) to (d)	(a) to (d)	(a) to (d)
	6° 6°	$+10^\circ$ -10°	(e) (f)	(e) (f)	(e) (f)	(e) (f)	(e) (f)



Note: Weapon Cluster can be 2,3,4,or 6 bombs

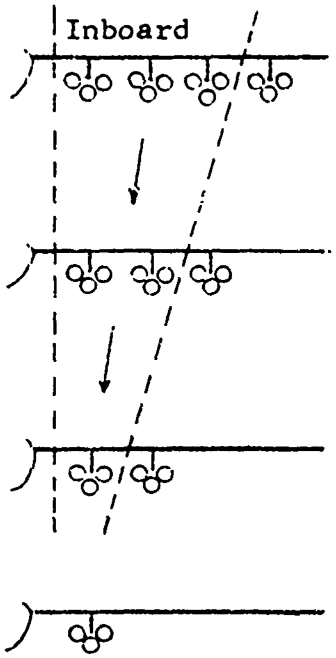
Table III A-1 PREDICTION CHART GUIDE: Weapon Cluster + Rack + Pylon (Outboard)

Table III A-2 COEFFICIENTS FOR CALCULATION OF EXTERNAL STORE AERODYNAMIC LOADS

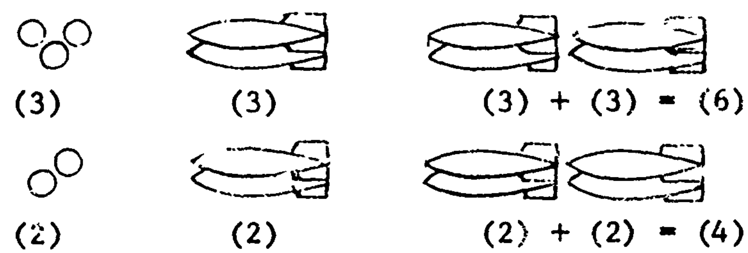
Weapon Cluster + Rack + Pylon Outboard Pylon		α	β	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_{MER}
C_N	(a)	16	0	.0000126	.00019	-.003519	-.000039	-.000177	-.003695	.052312	-.0014
	(b)	6	0	.0000055	.000174	-.003249	-.000031	-.000165	-.00302	.046517	-.0015
	(c)	-4	0	.0000016	.000264	-.006963	-.000051	-.000156	-.01429	.104971	-.0045
	(d)	-9	0	-.000006	.000358	-.0098[illegible]4	-.000128	-.000246	-.01859	.1530	-.0058
	(e)	6	+10	.0000066	.000296	-.00[illegible]791	-.000035	-.000168	-.00472	.0956	0
	(f)	6	-10	.0000054	.00024	-.005654	-.000045	-.00017	-.00402	.08097	0
C_Y	(a)	16	0	-.000002	.000189	-.005186	-.000236	-.000274	-.003221	.09423	.0021
	(b)	6	0	-.000001	.000148	-.00226	-.000116	-.000192	-.002362	.039732	.0014
	(c)	-4	0	-.000001	.000147	-.004289	.000077	.000042	-.004536	.05502	.0041
	(d)	-9	0	-.0000008	.0001319	-.003792	.0001232	.0001028	-.001509	.04098	.0040
	(e)	6	10	.000010	.000162	-.006417	-.000066	-.000333	-.006626	.087128	-.0015
	(f)	6	-10	-.000003	-.000004	.003514	-.000091	-.000015	.006264	-.03971	-.0006
C_m	(a)	16	0	-.000001	-.000184	.004161	.000001	.000059	.000338	-.051894	-.0040
	(b)	6	0	.0000004	-.000132	.003595	-.000007	-.000017	.000389	-.046446	-.0034
	(c)	-4	0	-.0000001	-.00007	.005205	-.000092	-.000174	+.0003	-.06860	-.0035
	(d)	-9	0	-.0000004	-.000004	.006119	-.000154	-.000299	-.000097	-.081475	-.0029
	(e)	6	10	-.0000006	-.000137	.003983	-.000009	-.000017	.00149	-.05221	-.0040
	(f)	6	-10	-.0000012	-.000119	.003631	-.000037	-.00003	.000293	-.044344	-.0028
C_n	(a)	16	0	.000002	.000001	.002706	-.000018	-.000047	-.000524	-.045114	-.0010
	(b)	6	0	-.0000004	.000011	.001322	-.000029	-.000051	-.00188	-.018915	-.0008
	(c)	-4	0	-.0000003	.000042	-.00167	.000016	.000022	-.002644	.023739	-.0013
	(d)	-9	0	-.000001	.000019	-.001619	.000042	.000061	-.001981	.02174	.0014
	(e)	6	10	.0000019	.000053	.003718	-.000056	-.000123	-.000985	-.06153	.0021
	(f)	6	-10	-.0000024	-.0000014	-.001456	-.000014	-.0000048	-.002011	.028859	.0002
C_ℓ	(a)	16	0	.0000002	-.000061	-.001348	.000042	.00004	.000535	.024005	-.0009
	(b)	6	0	.0000012	-.000079	.00087	.000046	.000059	.000716	-.014099	-.0012
	(c)	-4	0	.00000001	-.000063	.003143	-.000012	.000003	.0013	-.047025	+.0015
	(d)	-9	0	.0000015	-.000092	.004853	-.00001	.0000015	.000213	-.073241	-.0010
	(e)	6	10	-.000003	-.000087	-.001798	.0000084	.000063	.002527	.039753	-.0002
	(f)	6	-10	.0000021	.000022	.000212	.000055	.000058	-.0014859	-.015173	.0007

Note: C_{MER} = 0 for TER rack configurations

WEAPON LOCATION



FLIGHT CONDITION			SEE TABLE IV A-2, PAGE 298. PREDICT FORCE OR MOMENT FROM TABLE SECTION:				
N.M.	α	β	C_N	C_Y	C_m	C_n	C_l
0.5-0.95	$+16^{\circ}/-9^{\circ}$	0°	(a) to (d)	(a) to (d)	(a) to (d)	(a) to (d)	(a) to (d)
	6°	$+10^{\circ}$	(e)	(e)	(e)	(e)	(e)
	6°	-10°	(f)	(f)	(f)	(f)	(f)



Note: Weapon Cluster can be 2, 3, 4, or 6 bombs

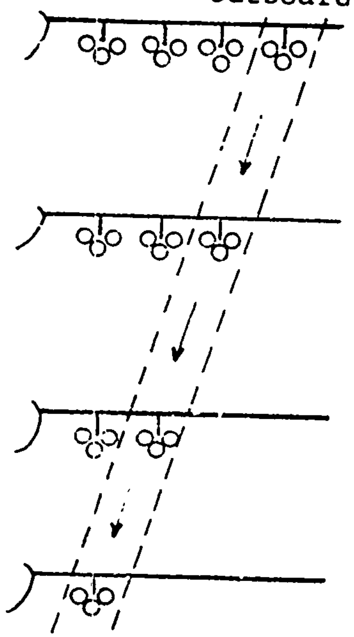
Table IV A-1 PREDICTION CHART GUIDE: Weapon Cluster + Rack + Pylon (Inboard)

Table IV A-2 COEFFICIENTS FOR CALCULATION OF EXTERNAL STORE AERODYNAMIC LOADS

Weapon Cluster + Rack + Pylon Inboard Pylon		α	β	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_{MER}
C_N	(a)	16	0	.0000022	.0002472	-.002939	-.0002361	-.0001882	-.0034984	.064635	$C_{MER} = 0$
	(b)	6	0	.0000075	.0001926	-.003577	.0000643	-.0001789	-.00278	.039268	
	(c)	-4	0	-.0000025	.0006889	-.021678	-.0000089	-.0002547	-.01296	.3084	
	(d)	-9	0	-.0000141	.0009421	-.0286388	-.0002069	-.0004086	-.013764	.424166	
	(e)	6	10	.0000005	.000266	-.0046136	-.0001246	-.0001776	-.0002748	.072832	
	(f)	6	-10	.000007	.0004322	-.012093	.0000239	-.0001831	-.004436	.163795	
C_Y	(a)	16	0	.0000463	.0001094	-.003897	.000282	-.0004038	-.0001347	.007799	
	(b)	6	0	.0000191	-.0000806	.003851	.0000197	-.000131	-.003837	-.0611542	
	(c)	-4	0	-.0000227	-.0001554	.0052563	-.0003556	.000122	-.006671	-.019344	
	(d)	-9	0	-.0000241	-.0002145	.0080027	-.0003445	.0001221	-.010243	-.05808	
	(e)	6	10	-.0000115	-.0000806	.0019274	-.000178	-.0000055	.0000134	.000036	
	(f)	6	-10	.0000088	-.000078	.001749	-.000156	-.0000287	+.0002753	-.001222	
C_m	(a)	16	0	-.0000069	-.0001997	.0053897	-.0001095	.0000653	-.0003341	-.056388	
	(b)	6	0	-.0000029	-.000175	.005241	-.000054	-.0000042	.000202	-.0640	
	(c)	-4	0	.000002	-.0000914	.0052603	-.0000208	-.0001423	.001666	-.077685	
	(d)	-9	0	.0000029	-.0000023	.0050193	-.0000515	-.0002559	.0017576	-.077859	
	(e)	6	10	-.0000042	-.00015	.0045336	-.0000675	.0000078	.0005544	.052544	
	(f)	6	-10	.0000031	-.0001362	.0042187	-.0000698	-.0000192	.00002	-.048737	
C_n	(a)	16	0	-.0000127	.0000604	.001807	-.0002708	-.0000927	.0001273	-.0003796	
	(b)	6	0	.0000144	.0000177	.0009493	-.0002743	-.0000437	.001264	.018321	
	(c)	-4	0	-.0000058	-.0000429	.0007925	-.0001042	.000053	.001595	.0041284	
	(d)	-9	0	-.0000047	-.0000602	.0010389	-.0000622	.0000864	.0019234	-.003505	
	(e)	6	10	-.0000082	.00011	.0018221	-.0002204	-.0001544	.0004205	-.012154	
	(f)	6	-10	-.00002	-.0000651	.001261	-.0003436	.0000065	.0017111	.030514	
C_l	(a)	16	0	.0000113	-.0001161	.0002465	.00028	.0000992	.0000446	-.02988	
	(b)	6	0	.0000162	-.0000174	-.0008097	.0003244	.0000545	.0006133	-.028633	
	(c)	-4	0	.0000158	.0000622	-.0007468	.0002578	-.0000139	.0012512	-.029383	
	(d)	-9	0	.0000158	.0000932	-.0008904	.0002356	-.0000166	+.0018523	-.02767	
	(e)	6	10	.0000109	-.0001521	.0006012	.0002629	.0001151	-.0001057	-.029531	
	(f)	6	-10	.0000198	.0001296	-.0033636	.0003668	.0000152	.0009738	-.006851	

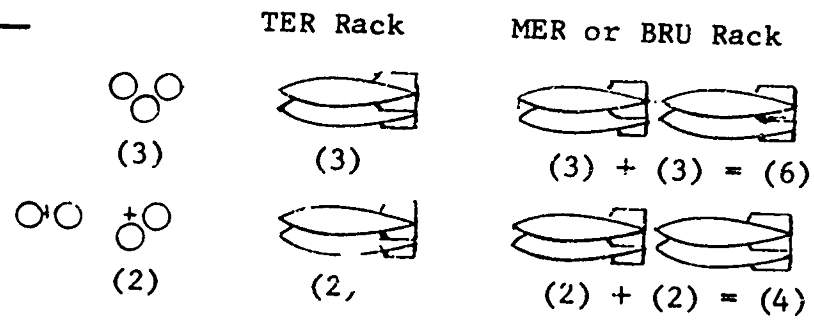
WEAPON LOCATION

Outboard



FLIGHT CONDITION			PREDICT FORCE OR MOMENT FROM TABLE SECTION:				
N.M.	α	β	C_N	C_Y	C_m	C_n	C_1
0.5-0.90	$+16^\circ/-9^\circ$	0°	(a) to (d)	(a) to (d)	(a) to (d)	(a) to (d)	(a) to (d)
	6° 6°	$+10^\circ$ -10°	(e) (f)	(e) (f)	(e) (f)	(e) (f)	(e) (f)

SEE TABLE V A-2, PAGE 300.



Note: Weapon Cluster can be 2, 3, 4, or 6 bombs

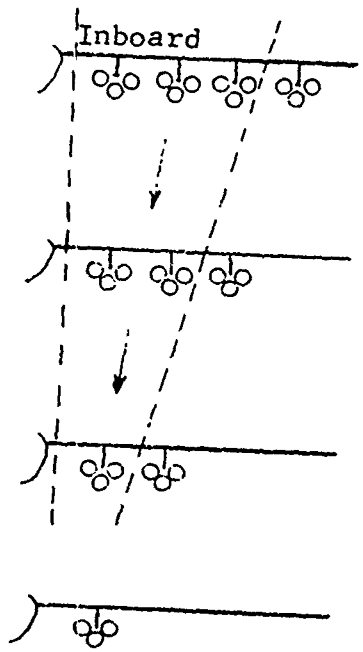
Table V A-1 PREDICTION CHART GUIDE: Weapon Cluster + Rack (Outboard)

Table V A-2 COEFFICIENTS FOR CALCULATION OF EXTERNAL STORE AERODYNAMIC LOADS

Weapon Cluster + Rack Outboard Pylon		α	β	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_{MER}
C_N	(a)	16	0	.0000101	.0001782	-.003207	-.0000263	-.0001578	-.0036218	.046416	+.0002
	(b)	6	0	-.0000025	.0001389	-.00185	-.0000512	-.0001611	-.002632	.02909	.0005
	(c)	-4	0	-.0000029	.0002027	-.004056	-.0000682	-.0001454	-.014492	.064927	.0024
	(d)	-9	0	-.0000066	.000324	-.007888	-.0001218	-.0002146	-.017693	.12226	.0052
	(e)	6	10	.0000042	.0002802	-.0056772	-.0000538	-.0001895	-.002864	.080067	.0030
	(f)	6	-10	.000034	.000169	-.0033375	-.0000448	-.0001422	-.004118	.049043	.0011
C_Y	(a)	16	0	-.0000152	.0002782	-.007328	-.0002927	-.0002682	-.003367	.133866	.0041
	(b)	6	0	-.0000088	.0001266	.0002836	-.0001649	-.0001971	.000536	.0069187	.0007
	(c)	-4	0	-.0000015	.0001769	-.0036213	.0000300	.0000003	.0006152	.045115	.0043
	(d)	-9	0	.0000021	.0002618	-.007198	.0001151	.0001057	.005264	.08232	.0075
	(e)	6	10	-.0000062	.0002619	-.006521	-.0001936	-.0003258	-.005881	.10404	.0036
	(f)	6	-10	-.0000087	.0000062	.0065318	-.0001634	-.000162	.0070115	-.07938	-.0022
C_m	(a)	16	0	-.0000005	-.0002063	.004831	.0000419	.0000857	.0001216	-.066622	-.0045
	(b)	6	0	-.0000001	-.0001522	.004331	.0000013	.0000022	-.000158	-.058174	-.0036
	(c)	-4	0	.0000001	-.0001051	.0058759	-.0000831	-.0001659	.0010301	-.07807	-.0042
	(d)	-9	0	-.0000002	-.0000551	.0064723	-.0001368	-.0002695	+.0011138	-.08517	-.0035
	(e)	6	10	0	-.0001726	.004948	.0000069	.0000057	.0005631	-.067462	-.0040
	(f)	6	-10	-.0000002	-.0001621	.004857	-.0000101	-.000009	-.0003474	-.064621	-.0034
C_n	(a)	16	0	.0000021	.0000205	.0016124	-.0000432	-.0000969	-.0005368	-.023678	-.0002
	(b)	6	0	-.0000002	-.0000071	.0005849	-.000029	-.0000583	-.0029647	.0043273	-.0005
	(c)	-4	0	-.0000012	.0000303	-.002232	-.000006	.0000044	-.003136	.036819	+.0006
	(d)	-9	0	-.0000015	.0000131	-.002281	.0000158	.0000419	-.002679	.036263	+.0006
	(e)	6	10	-.0000005	.0000301	.0027539	-.00009	-.0001556	-.002299	-.035433	-.0009
	(f)	6	-10	-.000001	-.0000387	-.002160	.0000322	.0000554	-.003487	.036149	-.0003
C_ℓ	(a)	16	0	.0000003	.000031	.0009487	-.0000207	-.0000256	-.0002054	-.016262	.0004
	(b)	6	0	.0000003	.0000096	.0005843	-.0000089	-.0000153	.0000253	-.009436	.0010
	(c)	-4	0	-.0000003	.0000351	-.002296	.0000026	.0000083	-.0002086	.03506	.0008
	(d)	-9	0	-.0000011	.0000544	-.0044968	.0000075	.0000265	+.000465	.068497	0
	(e)	6	10	-.0000005	.0000428	.0004747	-.0000202	-.0000237	-.0004463	-.009503	.0010
	(f)	6	-10	.0000012	-.0000114	.0000291	-.0000025	-.000011	.000087	.00127	0

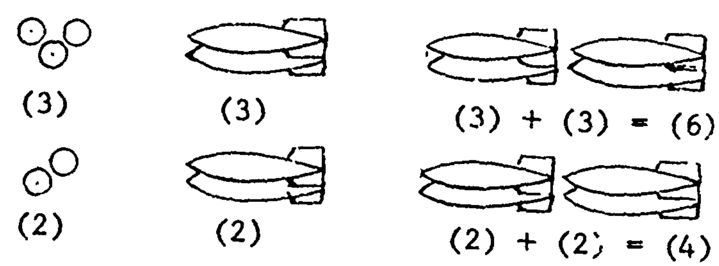
Note: C_{MER} =0 for TER rack configurations

WEAPON LOCATION



FLIGHT CONDITION			SEE TABLE VI A-2, PAGE 302. PREDICT FORCE AND MOMENT FROM TABLE SECTION:				
N.M.	α	β	C_N	C_Y	C_m	C_n	C_l
0.4-0.90	$+16^\circ/-9^\circ$	0°	(a) to (d)	(a) to (d)	(a) to (d)	(a) to (d)	(a) to (d)
	6° 6°	$+10^\circ$ -10°	(e) (f)	(e) (f)	(e) (f)	(e) (f)	(e) (f)

TER Rack MER or BRU Rack

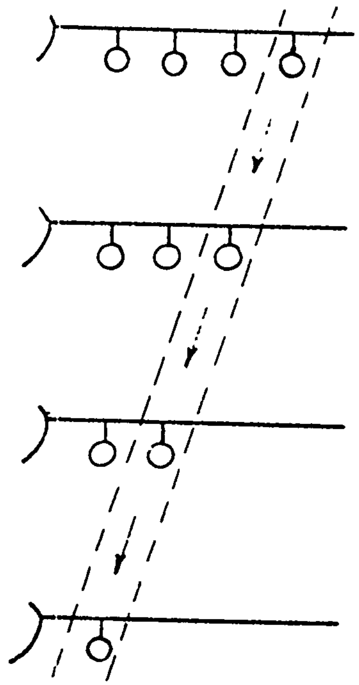


Note: Weapon Cluster can be 2, 3, 4, or 6 bombs

Table VI A-1 PREDICTION CHART GUIDE: Weapon Cluster + Rack (Inboard)

Table VI A-2 COEFFICIENTS FOR CALCULATION OF EXTERNAL STORE AERODYNAMIC LOADS

Weapon Cluster + Rack Inboard Pylon		α	β	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_{MER}
C_N	(a)	16	0	.0000035	.0004884	-.01052	-.0002813	-.0003812	-.004419	.175447	$C_{MER} = 0$
	(b)	6	0	.0000058	.0002413	-.0038	-.0000022	-.0002931	-.00203	.0497213	
	(c)	-4	0	-.0000011	.0005337	-.015447	.0000623	-.0002162	-.012552	.20828	
	(d)	-9	0	-.000011	.0006768	-.020953	-.0000649	-.0001772	-.014836	.29748	
	(e)	6	10	-.0000002	.0003481	-.006371	-.0001755	-.0002704	.0019147	.1021	
	(f)	6	-10	.0000045	.0003940	-.010327	-.0000239	-.0002164	-.00334	.144833	
C_Y	(a)	16	0	-.0000011	.000027	-.00645	-.0000102	.000002	.003809	.09779	
	(b)	6	0	.000001	-.0000444	.0000166	.000036	.00001474	-.003664	-.0033643	
	(c)	-4	0	.0000057	-.000071	.002776	.0000912	.0000058	.008816	-.051694	
	(d)	-9	0	.0000083	-.0000854	.003006	.000109	.0000308	.0112094	-.05832	
	(e)	6	10	.0000024	.0001078	-.005076	-.0000373	-.0001503	.004181	.06888	
	(f)	6	-10	.0000041	.0000883	.00512	.00003694	-.0000559	.01086	-.07723	
C_m	(a)	16	0	-.0000031	-.0002184	.00531	-.0000111	.0000829	-.000537	-.06623	
	(b)	6	0	.0000018	-.0002011	.005603	-.0000224	.000027	-.0010644	-.07169	
	(c)	-4	0	.0000002	-.000241	.009248	-.0000389	-.000067	.001759	-.12957	
	(d)	-9	0	.0000007	-.000229	.010973	-.000069	-.0001431	.0018856	-.15608	
	(e)	6	10	.0000016	-.0001672	.004275	-.000008	.0000346	-.000587	-.05431	
	(f)	6	-10	-.0000024	-.000223	.006413	-.000043	.0000331	-.001352	-.08104	
C_n	(a)	16	0	-.0000173	-.000018	.002004	-.000223	.0000024	-.000961	-.00292	
	(b)	6	0	-.0000156	.0000033	-.0005486	-.0002002	-.0000041	-.0027752	.036225	
	(c)	-4	0	-.0000046	.0000074	-.00171	-.0000617	.00002	-.003217	.03792	
	(d)	-9	0	-.0000076	.0000415	-.002726	-.000078	.0000433	-.00360	.054972	
	(e)	6	10	-.0000055	-.0000107	.003601	-.0001237	-.000095	-.002355	-.04227	
	(f)	6	-10	-.0000231	-.0000079	-.003122	-.000254	.000063	-.003236	.08805	
C	(a)	16	0	.0000022	.0000296	.0013328	-.0000212	-.000044	.0000266	-.022195	
	(b)	6	0	.0000023	-.0000228	.0015012	-.000039	-.0000068	.0000432	-.017637	
	(c)	-4	0	-.0000128	.0000385	-.002507	-.000153	.0000094	.0000417	.058533	
	(d)	-9	0	-.000014	.0000612	-.00462	-.0001648	.0000004	.0006644	.092556	
	(e)	6	10	-.0000014	.0000256	.001033	-.000041	-.0000913	.0003604	-.014233	
	(f)	6	-10	-.0000055	-.0000346	.000489	-.000079	.0000254	-.000357	.005581	

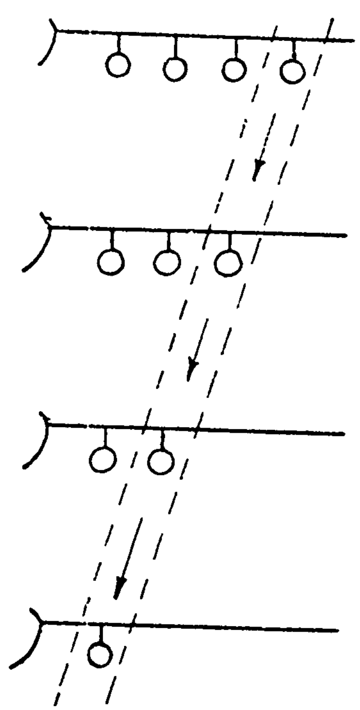


FLIGHT CONDITION			SEE TABLE VII A-2, PAGE 304. PREDICT EXTERNAL FORCE OR MOMENT FROM TABLE SECTION:				
N.M.	α	β	C_N	C_Y	C_m	C_n	C_1
0.6-0.90	$+16^\circ/-9^\circ$	0°	(a) to (d)	(a) to (d)	(a) to (d)	(a) to (d)	(a) to (d)
	6° 6°	$+10^\circ$ -10°	(e) (f)	(e) (f)	(e) (f)	(e) (f)	(e) (f)

Table VII A-1 PREDICTION CHART GUIDE: Single Weapon + Rack + Pylon (Outboard)

Table VII A-2 COEFFICIENTS FOR CALCULATION OF EXTERNAL STORE AERODYNAMIC LOADS

Single Weapon + Rack + Pylon Outboard		α	β'	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_N	(a)	16	0	-.0000004	-.0020058	.00806	.0000543	.0002888	-.006432	.17224
	(b)	6	0	.000002	.0004705	-.0003960	-.000004	.0000326	.006559	-.068648
	(c)	-4	0	-.0000024	.001907	-.006621	-.000011	-.0002477	-.008882	-.159751
	(d)	-9	0	-.0000066	.003014	-.01080	-.000235	.000497	-.020393	-.23363
	(e)	6	10	0	-.001554	.004180	.0000807	.000138	.003161	.15877
	(f)	6	-10	-.000003	.0000786	.0004042	.0000164	.0000961	.0057234	-.02736
C_Y	(a)	16	0	-.0000111	-.003343	.007415	-.0003203	-.0004273	-.001338	.47062
	(b)	6	0	-.000008	-.0018354	.0042186	-.0001279	-.000192	.004346	.25004
	(c)	-4	0	-.000004	-.0001773	.0000471	-.0000265	-.0000844	-.005202	.047616
	(d)	-9	0	-.0000008	+.00077	-.00296	.0000151	-.0000812	-.005654	-.05725
	(e)	6	10	-.0000247	-.005481	.011108	-.000307	-.00073	-.0121	.77572
	(f)	6	-10	-.000002	-.0002651	.000837	-.000159	-.0001595	.008125	.0684
C_m	(a)	16	0	.0000013	.002184	-.00804	-.0000211	-.0001625	.001306	-.20435
	(b)	6	0	-.0000007	.0007047	-.002723	-.000006	-.000056	-.003413	-.06094
	(c)	-4	0	.0000006	-.0003014	.001153	.0000354	.0000763	-.000496	.01871
	(d)	-9	0	.0000004	-.0003833	.001317	.0000539	.000109	.0004358	.024742
	(e)	6	10	.0000006	.000711	-.002505	-.0000368	-.0000982	-.002851	-.05913
	(f)	6	-10	.0000022	.00134	-.004783	-.0000277	-.0001186	-.003425	-.1242
C_n	(a)	16	0	-.0000014	-.000639	.002106	.0000437	.000095	-.00204	.05771
	(b)	6	0	-.0000005	-.0004175	.001458	.0000233	.0000524	-.001311	.03639
	(c)	-4	0	-.0000011	-.0002029	.0006816	.0000075	.0000241	-.001427	.02073
	(d)	-9	0	-.000001	-.000242	.0008334	.0000056	.0000188	-.001815	.0259114
	(e)	6	10	.0000003	-.00105	.003974	.000052	.0001269	-.0008079	.08647
	(f)	6	-10	-.000002	.0000949	-.000652	-.000003	-.0000173	-.002127	-.00087
C	(a)	16	0	.000002	.0007323	-.001842	.000039	.000048	.000034	-.093602
	(b)	6	0	.0000009	.000381	-.000968	.000017	.0000272	-.000322	-.04842
	(c)	-4	0	.0000004	.000033	-.00005	.000003	.000012	.000019	-.00676
	(d)	-9	0	-.0000001	-.0001304	.000453	-.000002	.0000117	.0001654	.01162
	(e)	6	10	.0000012	.0008846	-.002084	.000023	.0000571	.00095	-.111569
	(f)	6	-10	.0000003	.0000391	-.0001567	.0000188	.0000143	-.001287	-.008165



FLIGHT CONDITION			SEE TABLE VIII A-?, PAGE 306. PREDICT FORCE OR MOMENT FROM TABLE SECTION:				
N.M.	α	β	C_N	C_Y	C_m	C_n	C_l
0.5-0.90	$+16^\circ/-9^\circ$	0°	(a) to (d)	(a) to (d)	(a) to (d)	(a) to (d)	(a) to (d)
	6° 6°	$+10^\circ$ -10°	(e) (f)	(e) (f)	(e) (f)	(e) (f)	(e) (f)

Table VIII A-1 PREDICTION CHART GUIDE: Single Weapon + Rack (Outboard)

Table VIII A-2 COEFFICIENTS FOR CALCULATION OF EXTERNAL STORE AERODYNAMIC LOADS

Single Weapon + Rack Outboard		α	β	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_N	(a)	16	0	.000006	.000544	.0002258	.0000224	.0001206	-.00559	-.09877
	(b)	6	0	.000001	.0001833	-.000056	-.0000121	.0001315	-.06408	.029042
	(c)	- 4	0	-.000008	-.000213	-.0006255	-.0000792	-.0001333	-.005468	.07575
	(d)	- 9	0	-.0000134	-.000392	-.0002011	-.0001404	-.000195	-.01761	.11515
	(e)	6	10	-.0000055	-.001644	.00415	.0000491	.000096	.004205	.18519
	(f)	6	-10	-.0000035	.001223	-.003913	-.0000521	-.0000725	.004806	-.11858
C_Y	(a)	16	0	-.0000046	-.002434	.006317	-.000214	-.00029	-.002047	.3144
	(b)	6	0	-.0000013	-.001511	.003477	-.0001422	-.000281	.00327	.21268
	(c)	- 4	0	.0000002	.0005617	-.001981	-.0000216	-.000097	.000881	-.0444
	(d)	- 9	0	.000004	.0009737	-.003429	-.0000118	-.0001663	-.000915	-.08536
	(e)	6	10	-.0000037	-.003268	.007515	-.0001224	-.000367	-.00524	.41886
	(f)	6	-10	.0000109	.001816	-.004276	-.0000765	-.0001195	.011552	-.20974
C_m	(a)	16	0	-.0000046	-.0003116	-.000402	.0000269	.0000098	.0017064	.0582
	(b)	6	0	-.0000013	-.000081	-.0001362	.0000206	.0000135	-.003532	.014843
	(c)	- 4	0	.000002	.000069	.000123	.000028	.000043	-.00051	-.02260
	(d)	- 9	0	.0000004	-.0000152	.000077	.0000496	.000082	.00093	-.01153
	(e)	6	10	.0000013	.0008703	-.002617	-.0000303	-.000083	-.002561	-.08606
	(f)	6	-10	.0000016	+.000745	-.002662	-.000006	-.000059	-.003672	-.07074
C_n	(a)	16	0	-.0000025	-.0005154	.0016293	.000061	.0001262	-.001953	.04605
	(b)	6	0	-.0000008	-.0004437	.001681	.0000454	.0001006	-.001482	.032694
	(c)	- 4	0	-.0000011	-.0003168	+.0011596	.0000131	.0000471	-.001003	.02811
	(d)	- 9	0	-.0000014	-.000102	.0005686	.000008	.000044	.000055	.004583
	(e)	6	10	-.000002	.000244	-.001301	+.000003	-.000027	-.002845	-.01498
	(f)	6	-10	-.0000007	-.000797	.00319	.000058	.0001628	-.0001654	.06139
C	(a)	16	0	0	-.0000321	.000071	-.000003	-.000006	.00009	.00483
	(b)	6	0	.0000001	.000007	-.000021	.0000002	-.0000002	.000063	-.000798
	(c)	- 4	0	.0000001	.000051	-.000151	-.0000009	-.000002	.0000302	-.0057
	(d)	- 9	0	0	.000064	-.0001936	-.000003	-.000004	-.000081	-.006623
	(e)	6	10	.0000002	-.000008	-.000008	-.000003	-.000007	.000168	.002378
	(f)	6	-10	0	.0000544	-.000182	.0000005	-.000002	-.0001478	-.005754

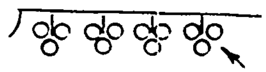
EXAMPLE PROBLEMS

$\alpha = 16^\circ \quad \beta = 0^\circ$

$MN = 0.80$

Normal Load Coefficient
<u>Outboard</u> Station

Configuration



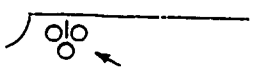
BLU-1CB Weapon
TER Rack + Pylon

ℓ = 143.5 in
D = 18.2 in
C = 84.0 in
Δx = 53.0 in
$\frac{PA}{FA}$xFSPD = 1250.6

$$\frac{C_{N_{PA}}}{NFB^2}(AR) = .052312 + .00019\ell - .003519D - .000039C$$
$$-.000177\Delta x + .0000126\frac{PA}{FA}(FSPD) - .00369M^2$$
$$= .052312 + .02725 - .064 - .003275$$
$$- .00938 + .01575 - .00236$$

$$\frac{C_{N_{PA}}}{NFB^2}(AR) = .01647$$

Note: $C_{MER} = 0$ for TER



M-117 Weapons (6)
MER Rack + Pylon

ℓ = 185.8 in
D = 16.5 in
C = 123.0
Δx = 58.0
AR = .2423
$\frac{PA}{FA}$xFSPD = 377.0

$$\frac{C_{N_{PA}}}{NFB^2}(AR)\ \frac{NB^2}{NFB^2} = .052312 + .00019\ell - .003519D - .000039C$$
$$-.000177\Delta x + .0000126\frac{PA}{FA}(FSPD) - .00369M^2$$
$$-.0014$$

$$\frac{C_{N_{PA}}}{NFB^2}(AR)\ \frac{36}{9} = .052312 + .0353 - .05806 - .00479 - .01028$$
$$+.00475 - .00236 - .0014$$
$$= .016872 - .0010$$
$$= .015872$$

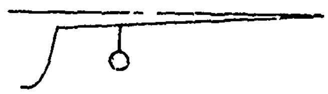
$$\frac{C_{N_{PA}}}{NFB^2}(AR) = \frac{1}{4}\ (.015872) = .00397$$

3.1 Corrections for Supersonic Mach Numbers

The statistical methods of data correlation used to develop the aerodynamic force and moment equations previously described for subsonic speeds could not be used to establish similar coefficients for supersonic speeds. From the F-111 wind tunnel testing, only a few of the total number of configurations were tested at supersonic speeds and the volume of data required for adequate sampling and curve fitting were not available. It was necessary then to use a different approach to establish supersonic coefficients based on the available data.

The equations produced by the statistical methods used are linear and can, therefore, be easily corrected or modified. The corrections are in the form of ratios developed at a constant angle of attack of the store with respect to the free stream over the range of Mach numbers for which data is available, M = .95 to M = 1.6. These supersonic correction ratios are formed by taking the store force or moment coefficient at the various supersonic Mach numbers to the force or moment coefficients at M = .95. They are shown in Figures 4A through 7A. The supersonic correction ratios can be directly applied by factoring the subsonic coefficient values developed from the statistical equations for the appropriate configuration at M = .95, to obtain the supersonic coefficient.

The supersonic correction ratios should be applied only to single stores. A special effort should be made to compare the configuration being evaluated with the F-111 configurations tested at supersonic speeds to insure that geometric similarity exists.



Single Store

Wing Sweep = 50°

Inboard Pylon Location

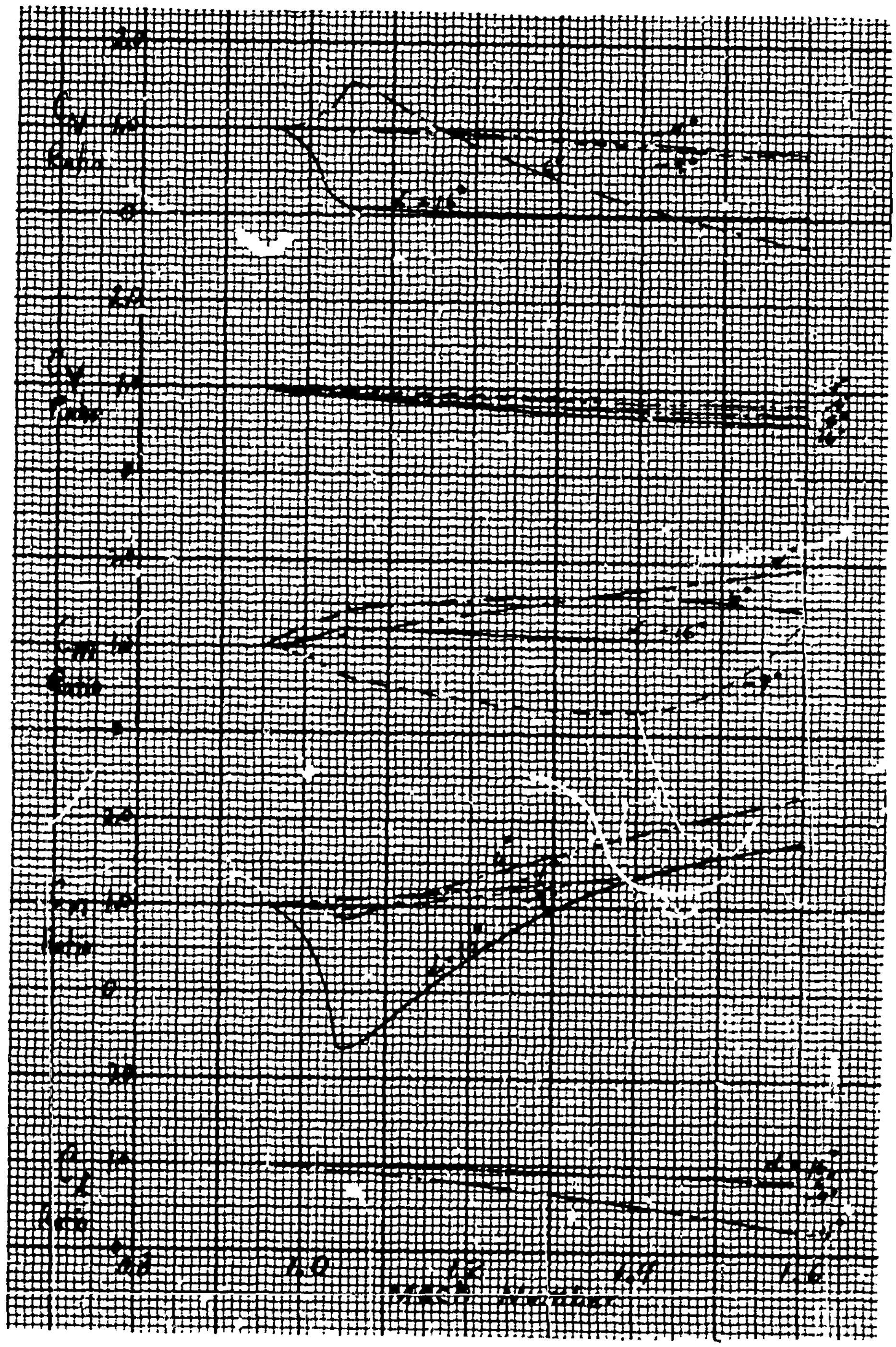


Figure 4A Ratio of the External Store Aerodynamic Force or Moment Value at Supersonic Speed to the Value at M = 0.95.

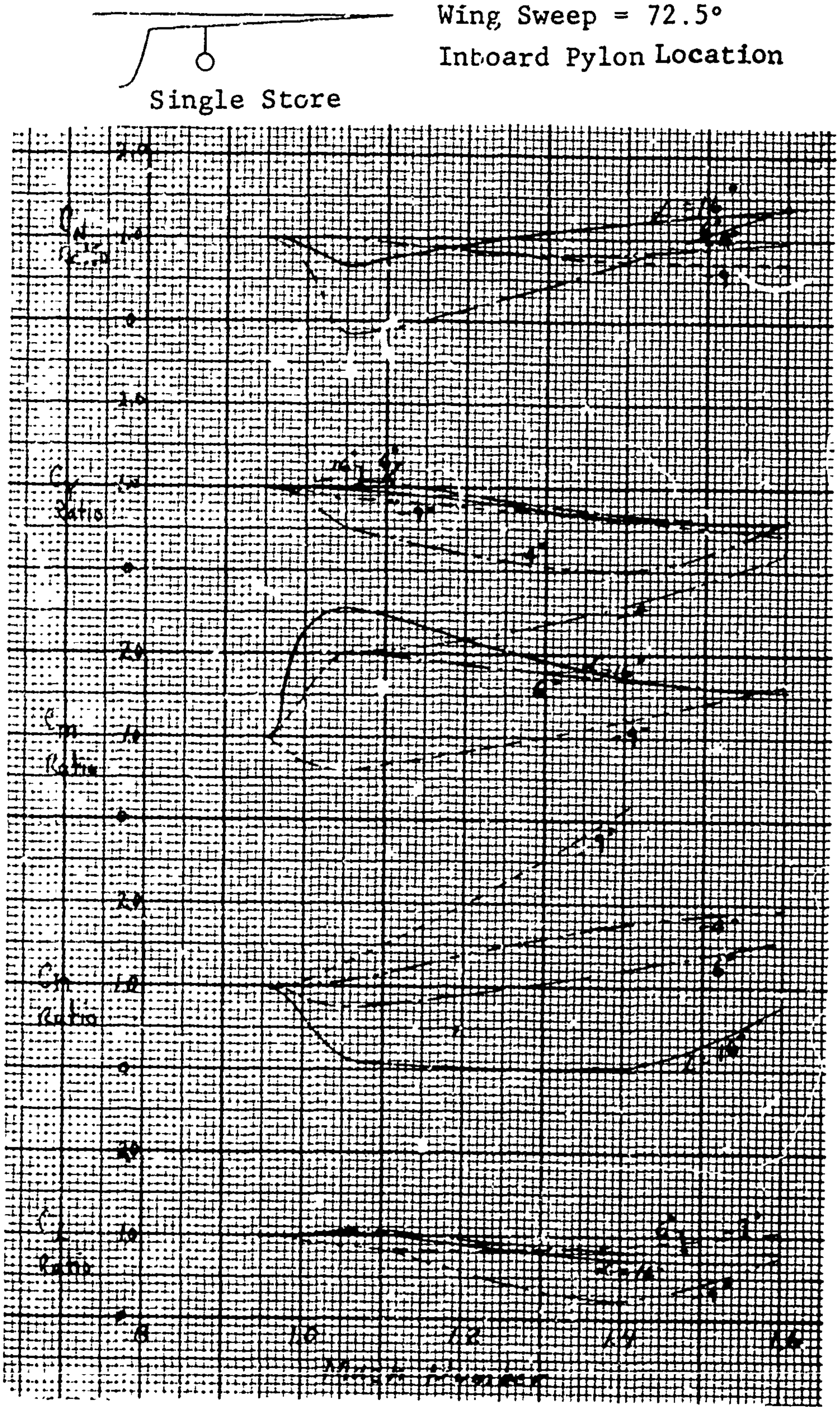


Figure 5A Ratio of the External Store Aerodynamic Force or Moment Value at Supersonic Speed to the Value at M = 0.95.

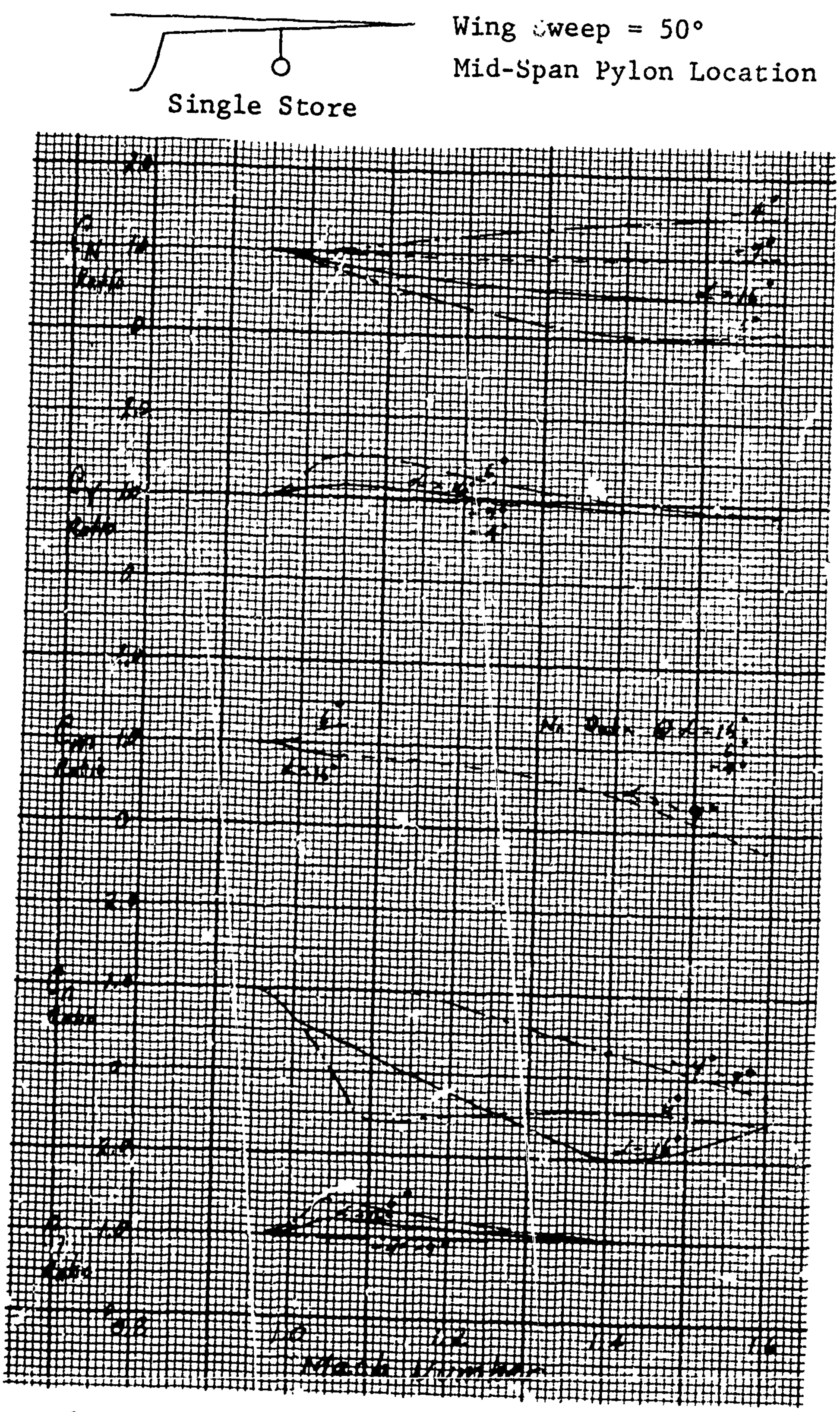


Figure 6A Ratio of the External Store Aerodynamic Force or Moment Value at Supersonic Speed to the Value at M = 0.95.

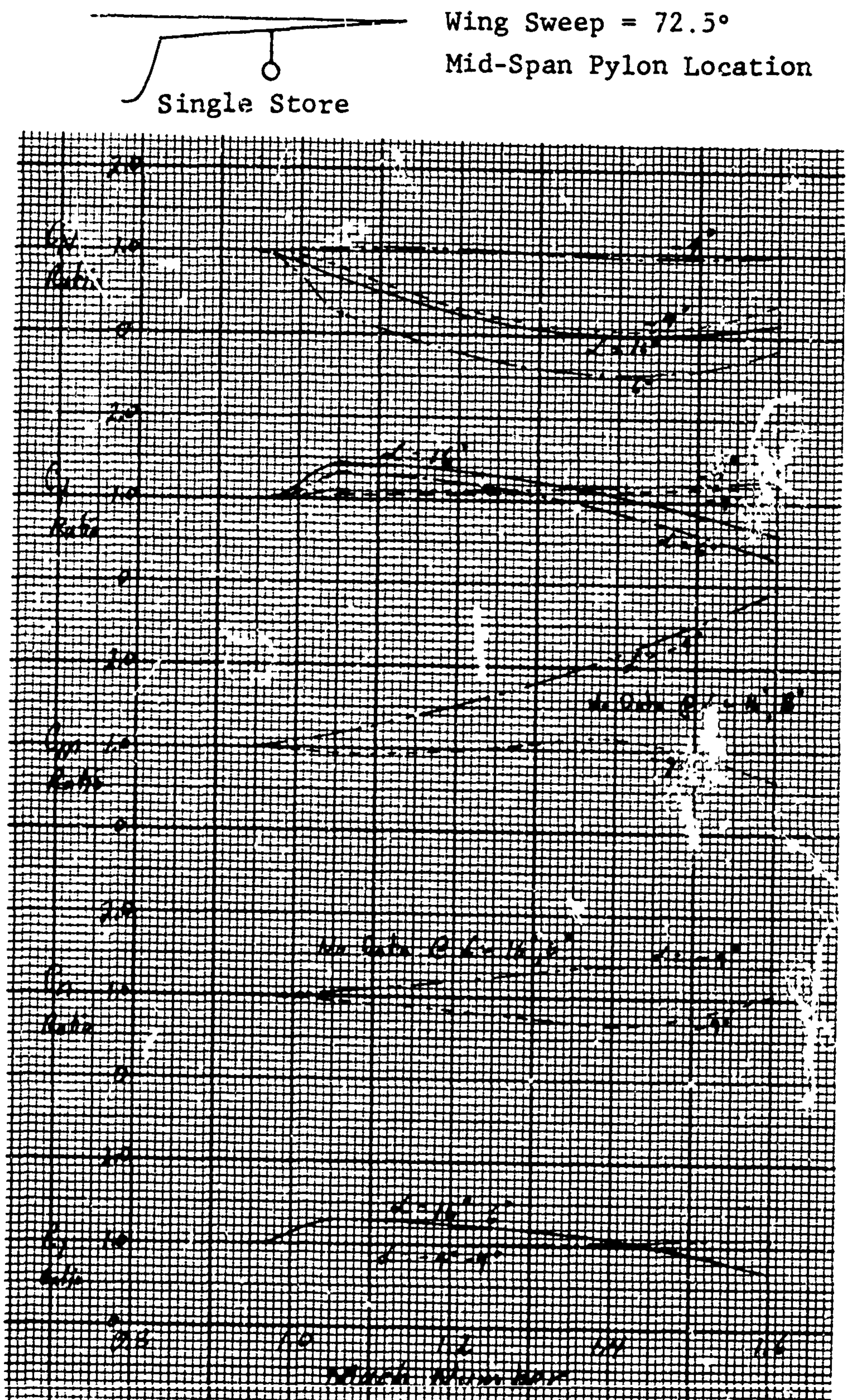


Figure 7A Ratio of the External Store Aerodynamic Force or Moment Value at Supersonic Speed to the Value at M = 0.95.

3.2 Corrections for Pylon Length

One geometry parameter which could have a significant effect on the various components of aerodynamic force or moment acting on the external store configuration is the distance of the store below the wing surface. This parameter was not tested on the F-111 since the external store pylon length was a constant.

Data for this parameter for single-stores is shown in Figure 8A from Reference 16. From this reference it can be seen that the vertical displacement of the store makes a substantial difference to the magnitude of the normal force acting on the store but in this particular test does not materially affect the other store forces or moments which were measured. It would not be proper to assume that the results of these tests are universally true for all configurations. It may be possible, however, to draw generalized conclusions from such tests which would be of value in establishing trends for other configurations. Because the data base is so limited the conclusions should be used only to establish data trends from which recommendations can be made for wind tunnel testing on those single-store configurations which exhibit critical design loads.

The trend effects of store vertical location shown in Figure 8A give an indication of the coefficient corrections that may be required of the parameters derived in Section 3A. The normal load correction will tend to produce a positive load on the store, which is a function of angle-of-attack, as pylon length is decreased. There is no correction requirement indicated for the pitching moment. The side loads correction would tend to be a constant applied at all angles of attack. The total yawing moment coefficient corrections will also tend to vary as a function of angle-of-attack and there is no correction requirement avail- for the rolling moment coefficient.

The data could be applied as a correction to the predicted values from Section 3A for similar geometric arrangements. This would be accomplished by multiplying the predicted value of a particular force or moment by the ratio of the force or moment from Reference 16 at the new vertical location to the value at the vertical location equal to the F-111 data of Section 3A. The coefficients shown in Figure 8A, however, are based on a different reference area than those defined in Section 3A and any direct numerical comparisons made between the coefficients will require a correction. All of the coefficients shown in Figure 8A are referenced to the store maximum cross-sectional area.

The ratio z/d is defined as a ratio of the distance z, which is the minimum distance from the wing lower surface to store longitudinal axis, to the dimension d, which is the maximum store diameter. The corrections for pylon length account for pylons shorter than the pylons used for the F-111 ($z/d = 1.5$). Data for pylons with a greater length have not been accumulated.

For other store groupings and weapons cluster configurations, the aerodynamicist must make a choice of expanding the empirical techniques developed in this report or of utilizing a correlation of experimental and theoretical aerodynamic results to arrive at predictions for new aerodynamic configurations. Theoretical aerodynamic procedures such as those contained in References 26, 27 and 28 have recently been developed which are able to analyze very complex geometric arrangements. Some of these programs will actually analyze aircraft configurations with some representation of single external store installations. For the more complex external store arrangements with several wing positions occupied, theoretical techniques for aerodynamic analysis are much further away and development of empirical prediction techniques based on correlations of experimental data will be useful for many years to come.

From Reference 16 (p. 81)

M = 0.95, Single Store + Pylon

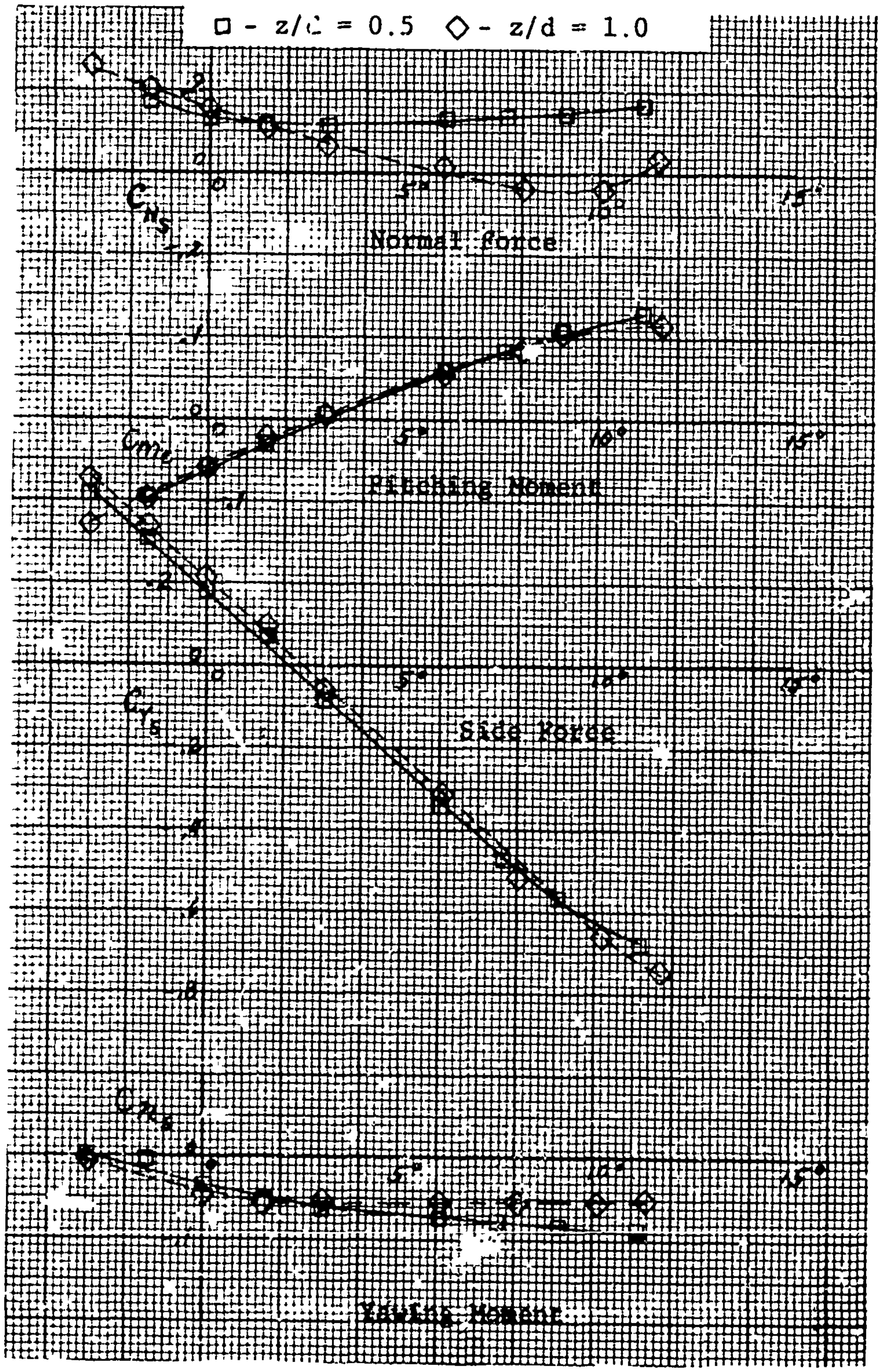


Figure 8A Effect of Store Vertical Location

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